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AERO/SPACE ENGINEERING

REVIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT • MISSILES • ROCKETS • SATELLITES • SPACECRAFT

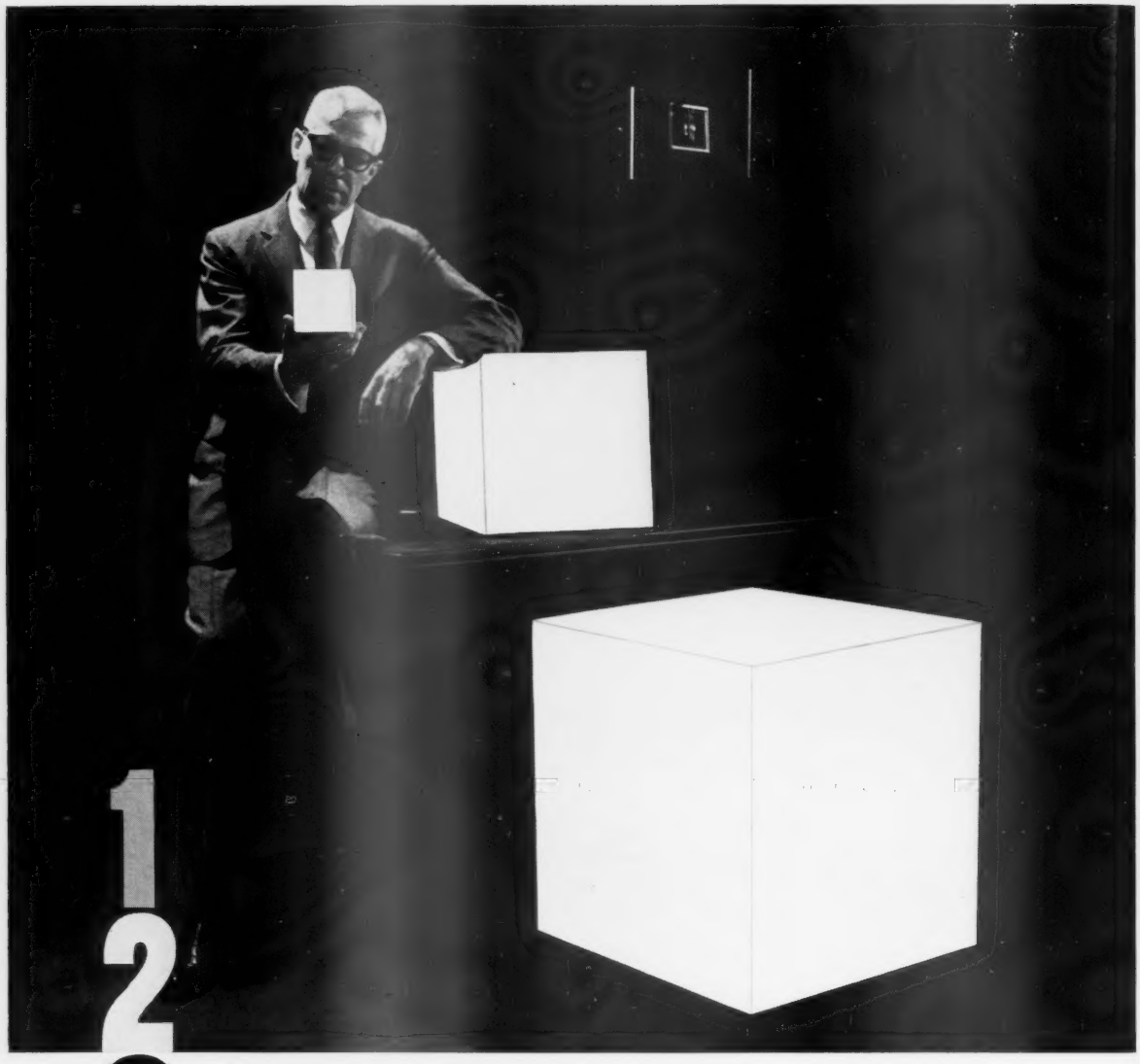
New IAS Constitution

See Editorial . . . page 28

PICTORIAL: *Missiles at Mugu* . . . page 10

AUGUST / 1959

XUM



3 generations of airborne digital computers (but we can't show you their configurations)

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The larger size has been *in production* since 1957. The middle-sized one (a quarter the size of today's) will be in production in 1960. And the micro-miniaturized version in the engineer's hand will be operational in 1962—only .3 cubic feet in volume.

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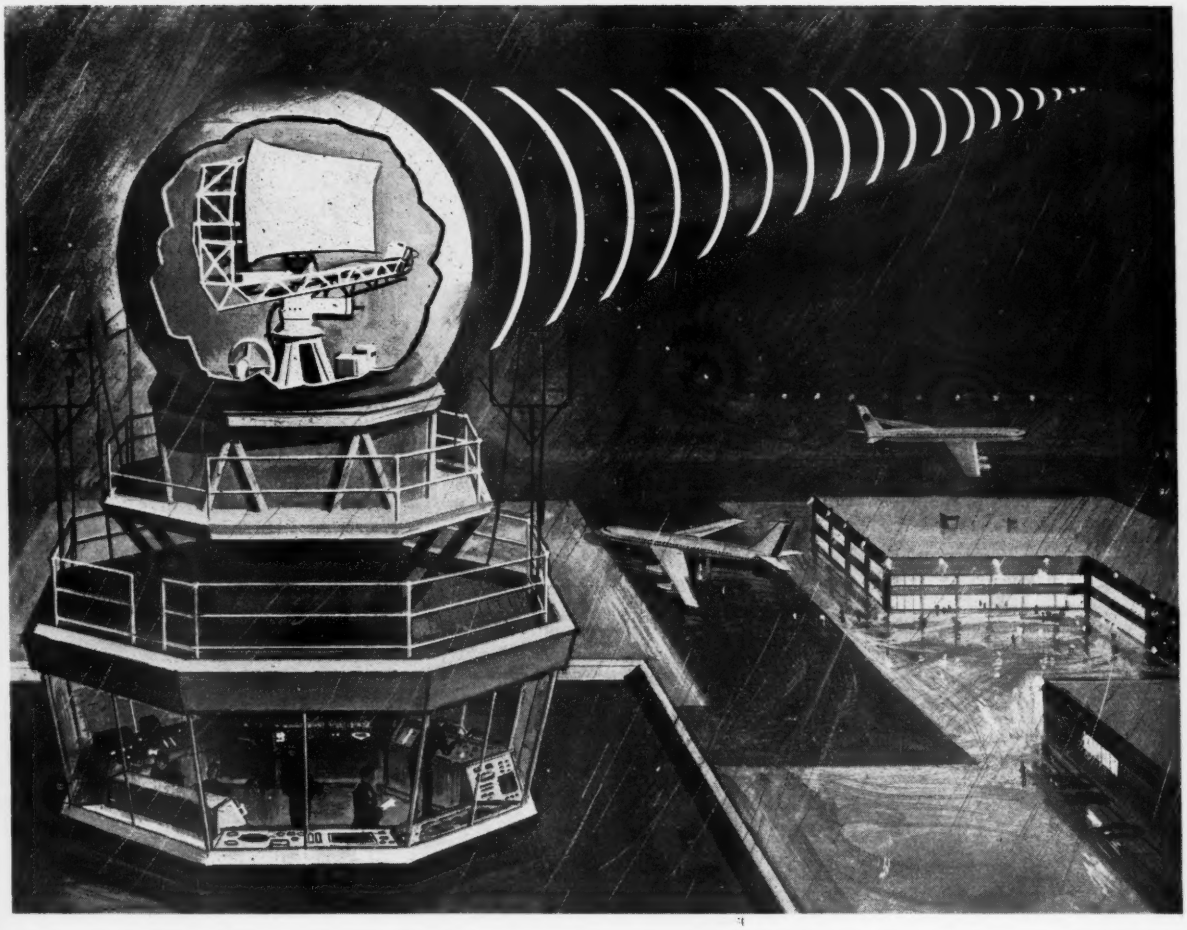

HOW TO KEEP AN EYE ON RUNWAYS
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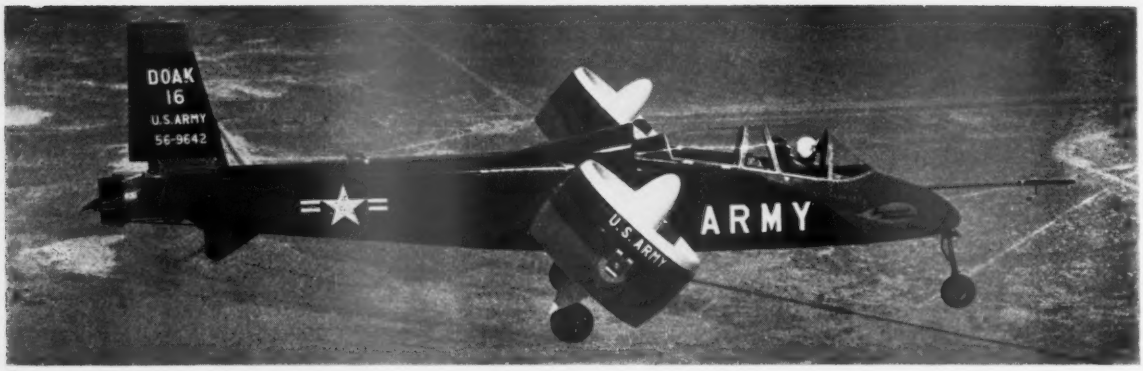

On our cover—*An exclusive photo of the Doak Army VZ-4DA shows the VTOL aircraft in conventional flight. In view above, the plane's ducted fans are at 45 degrees as it slows and prepares to hover. While the Army—with observation and liaison in mind—is financing current development, Edmond R. Doak, President and General Manager of Doak Aircraft Co., Inc., also sees a potential for the "16" as a commercial transport. The aircraft is powered by a single 840-hp. Lycoming T-53 shaft turbine engine. Span is 25½ ft., length 32 ft., and height 10 ft. Weight empty is 2,300 lbs.; gross weight is 3,000 lbs. (This aircraft was the subject of "Design Philosophy and Test Experiences of a VTOL Aircraft," by Bruno J. Uberti and James B. Reichert, of Doak Aircraft, presented at the IAS National Summer Meeting, June 16–19, in Los Angeles. Copies in limited number are available from the IAS Special Publications Dept.)*

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. . . formerly *Aeronautical Engineering Review*, is published monthly by the Institute of the Aeronautical Sciences, Inc., at 20th and Northampton Streets, Easton, Pa. Headquarters and Editorial Offices: 2 East 64th Street, New York 21, N.Y. (TEmpleton 8-3800). Western Office: 7660 Beverly Blvd., Los Angeles 36, Calif.

Subscription rates: United States and possessions, 1 year, $5.00; single copies, $0.50. Foreign countries including Canada (American currency rates), 1 year, $6.00; single copies, $0.50.

Second-class mail privileges authorized at Easton, Pa. This publication is authorized to be mailed at the special rates of postage prescribed by Section 132.122.

Notices of change of address should be sent to the Institute of the Aeronautical Sciences, Inc., 2 East 64th Street, New York 21, N.Y., at least 30 days prior to actual change of address.

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"The prestige magazine of the Aerospace Industry"

AERO/SPACE ENGINEERING

VOLUME 18 / NUMBER 8 **August 1959**

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LETTERS to the Editor

Reliability—and Rationality

The letter to the Editor in the January, 1959, issue of AERO/SPACE ENGINEERING by IAS President William Littlewood and the response to this letter in the March and May issues illustrate three basic misconceptions with respect to the problem of reliability—namely, that the problem is new, that its emergence is the result of lack of "practical approach and experience" of the young scientist and engineer, and that it can be handled by conventional methods without an effort to establish the theoretical and practical basis for its solution under the various circumstances under which it arises.

The general approach by the engineering profession to the old problem of structural safety, which is just a different name for the problem of reliability with respect to mechanical failure, shows a deep-seated reluctance to deal with the problem in a rational manner. Among the many hundred papers dealing with problems of stress analysis and methods of solution of differential equations arising in such problems, or reporting the results of deformation-and-strength tests performed on material specimens, there appears only an occasional paper attempting to analyze the process by which the results of stress analysis and materials research could be correlated in actual design in order to establish the mechanical reliability of the designed system. There is in the engineering profession a marked lack of interest in the associated problems of safety and reliability of systems. Thus, for instance, a few years ago a proposal of this writer to a Federal agency to sponsor an International Conference (most of the fundamental work in this field has been done in Europe and Australia) on Safety and Reliability with respect to mechanical performance was turned down as being of minor importance in comparison to conferences on other subjects that appeared to be of much greater urgency. Even last year a discussion of the same subject with a research agency of that branch of the Defense Department that should be most vitally affected by our lack of knowledge in this field showed the same indifference arising from a complete lack of awareness even of the existence of a specific problem. It is quite generally felt in the engineering profession that there is no problem, and that all that is required to establish reliability is the application of "engineering common sense and experience."

It has been in the fields of heat-exchanger and airframe design that the inadequacy of this "practical" approach has been first shown up since it is in those fields that the problem of design for a specified life arose, coupled with operational requirements that impose a severe penalty on overdesign. In the design of missiles, the problem is magnified a hundredfold by the fantastic increase in the number of critical components of the system, as well as by the much higher operational penalty paid for overdesign; it has become quite obvious that it can no longer be handled by that kind of "engineering experience" that is based on nothing but a lack of factual knowledge of the basic aspects of the problem.

Thus, for instance, the statement in L. A. Rodert's letter in the May issue that "wearout failures occur with time dependency expressed by the well-known Gaussian distribution" makes it appear that we were dealing with a well-established fact. However, in the extensive investigations of the distribution of fatigue failures, as well as of creep failures, both of which certainly qualify as "wear-out" failures, Gaussian distributions can hardly be found. Conventional statistical methods based on this distribution are therefore completely misleading in reliability studies; life predictions on their basis may be off by several orders of magnitude in spite of the application of statistical measures "of high efficiency" since these "statistics" have no physical relevance.

The above example illustrates how little we know and how much we have to learn, with respect to both theory and the effects of improvements of production techniques and reduction of tolerance levels, before we can approach the problem of reliability rationally and with hope of success.

Before the various steps outlined in Mr. Rodert's letter can be taken, it appears that an effort should be made on a more fundamental level to establish the theoretical and practical basis of an analytical approach to the problem of reliability in the different fields of engineering (mechanical, electronic, etc.) involved. This could not be achieved by statisticians alone, who are concerned with methods rather than with the physical basis of their validity, or by "practical" engineers unfamiliar with probability considerations and statistical methods, or by theoretical scientists unfamiliar with production and with the relations between imposed levels of tolerance and production procedures. Rather it would require an integrated approach by a small group of investigators familiar with the various aspects of the problem and prepared to develop the necessary methods even in the face of the opposition from "practical engineers" that invariably arises whenever an attempt is made to bring some rationality into problems of reliability and safety.

Alfred M. Freudenthal, MIAS
Prof., Civil Engrg., Columbia Univ.
Chm., ASCE Com. on Safety Factors

On Oxygen Mask Development

Civil airplanes are now operating at altitudes where the lack of adequate oxygen for only a limited period can lead to unconsciousness or death. In pressure cabins, masks are required as stand-by equipment for use by passengers in event of failure of plane pressurization at high altitudes. As a further safety measure, one pilot must wear an oxygen mask at all times above 25,000 ft.

An oxygen mask must provide adequate arterial oxygen concentration for the indicated range of altitudes being flown. Also it should be comfortable, convenient, and economical. In its design and construction, though, any compromise should necessarily be resolved in favor of the paramount requirement of effectiveness. Situations may arise where the use of disposable masks having restricted ceilings, or masks without headstraps, will prove inadequate and entail calculated risks beyond a marginal nature.

Having been closely associated with the investigation and manufacture of oxygen masks since 1938 when pipe stems were still being used, I have developed a continuous-flow oxygen mask which satisfies such criteria. A single universal size covers both the mouth and the nose. Wide flexible flanges seal against the user's face. Malleable wire loops embedded in the rubber body over the nasal and oral areas may be formed individually against the face. It is light in weight, and an exhalation deflector prevents fogging of eyeglasses. A detachable bag may be used optionally for rebreathing or with a simple change as a reservoir to accumulate 100% oxygen.

Physiological evaluations showed "comfort on the faces of small, medium, and large subjects for 45-min. tests; negligible valve resistance maintains with established rates of oxygen flow an adequate partial pressure of oxygen in inspired air under conditions of rest and mild activity at simulated altitudes of 10,000, 20,000, 25,000, and 30,000 ft. in the low-pressure chamber." Flight tests at altitudes exceeding 10,000 ft. demonstrated "an easy press fit to any size or shape of facial bone structure, wearability without helmet, no pull of skin beneath eyes when turning head, agreeable softness of material, restful breathing with extreme comfort, and no necessity to pull tightly around the neck or head as with other masks."

A new universal constant flow oxygen mask is now available[1] for use with rebreathing up to 30,000 ft. and 100% oxygen at higher altitudes.

Allan M. Russell, AIAS
Consultant

[1] Manufacturer: National Cylinder Gas, Div. of Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

(*Continued on page 65*)

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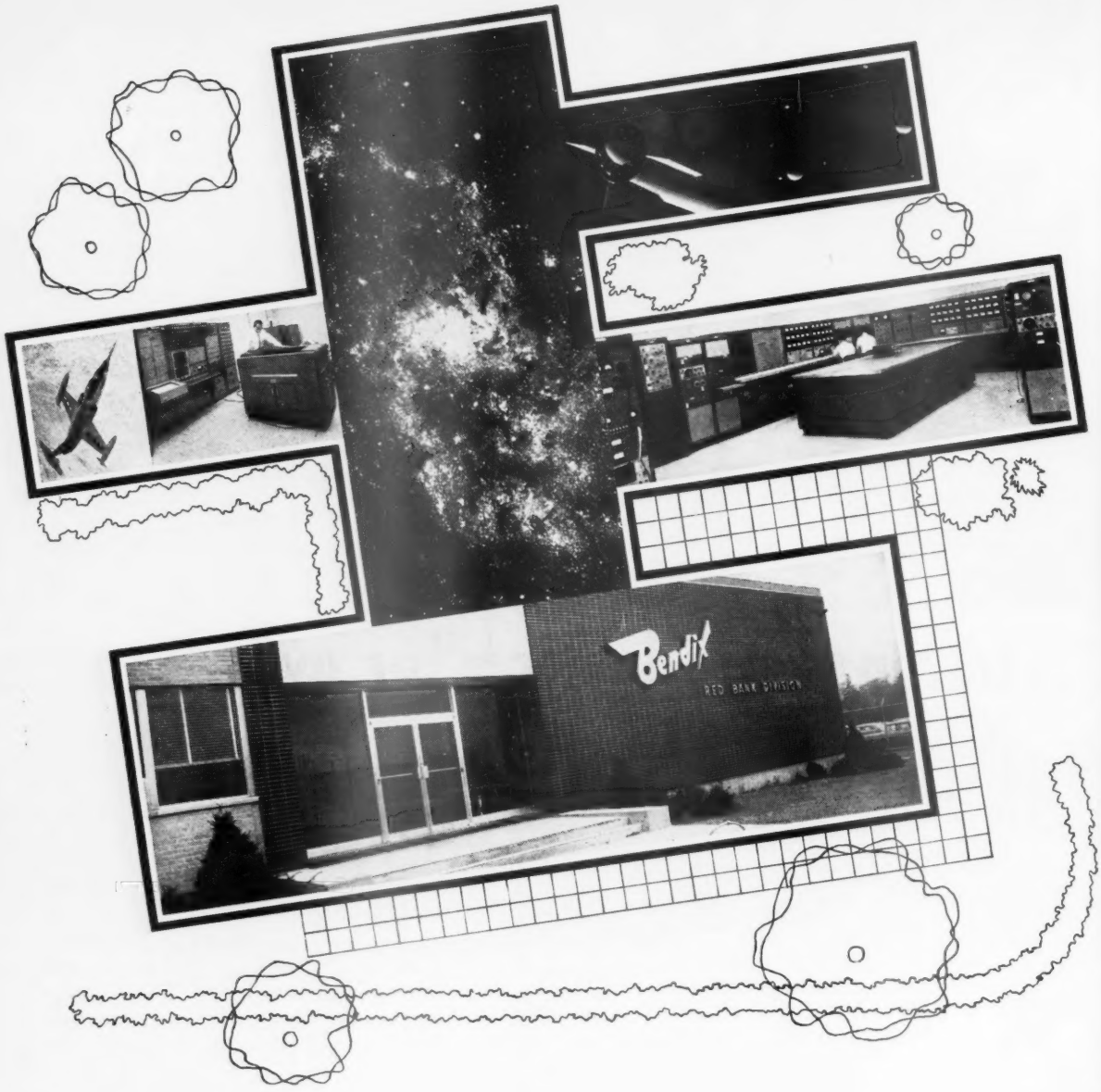

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Want to be an Executive?

Management is actively looking for engineers who have the desire and ability to become administrators

by
James M. Jenks

In a sense, this is the golden age for engineers. Once buried in corporate obscurity, many of them have emerged today as likely heirs apparent to the big jobs — and the big rewards — of business and industry. One impressive indication of this growth is that money spent in research and development over the past fifteen years has increased six-fold.

Despite this stepped-up activity, however, the once disorganized scramble for engineers seems to have ended . . . at least temporarily. And perhaps it's a good thing. Actually, the more perceptive engineers had always realized that unusually high starting salaries were often illusory. The gap between money being offered beginners and the incomes of experienced men was narrowing rapidly. Further, more and more thinking technical men concluded that even top engineering salaries are low when compared with the remuneration of highly placed general executives.

A Plan to Help the Engineer Succeed

Happily, there is a route to increased incomes that is satisfying to both engineer and company alike. This route leads into *management*. It is no easy road but the rewards are great for those willing and able to follow it.

In the vast, complicated world of business the engineer has much to learn. As a manager his duties will bring him into contact with accountants and buyers, advertising men and salesmen, lawyers and other executives. A strange new set of circumstances confronts him. He must gain confidences and be understanding, learn and instruct, be sympathetic, paternal or commanding as conditions require . . . and all in the midst of a business organization about which his knowledge is limited.

Actually, it comes down to this: To succeed as a business executive, the engineer must learn the art of making decisions quickly and accurately. And this ability is, of course, directly dependent upon knowledge. The "principles" of business—while not as scientific and inexorable as those of engineering—are no less important . . . no less essential to efficient procedure.

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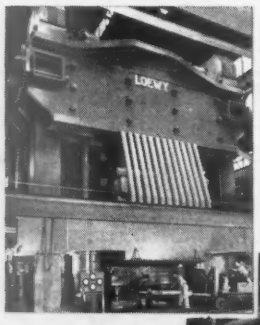

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IAS News

. . . a record of people and events of interest to Institute Members

Point Mugu Trip, Display of 30 Missiles Highlight IAS National Summer Meeting

Rear Adm. J. P. Monroe, Commander, Pacific Missile Range, Extends Welcome to 345 Institute Members

A FIELD TRIP to the U.S. Naval Missile Center, Point Mugu, Calif., and inspection of one of the most impressive displays of U.S. Army, Navy, and Air Force guided missiles ever staged highlighted the National Summer Meeting. An estimated 345 IAS members attended the classified (Secret) event on June 19.

From early morning (buses left Los Angeles beginning at 6:30 a.m.) until late afternoon, visitors were special guests of the Navy Department. Its welcome was extended by Rear Adm. Jack P. Monroe, Commander, Pacific Missile Range, with headquarters at the Center.

Admiral Monroe, in addressing IAS visitors, expressed the hope that the display of the nation's missile arsenal, and the opportunity to discuss the missiles with authoritative personnel, "will advance your own work in missile and satellite technology."

Following was a briefing on "Pacific Missile Range Facilities and Capabilities" by Comdr. R. F. Freitag, USN, Range Planning Officer. Visitors then proceeded to viewing stands in the launch pad area, alive with preparations to launch and recover Regulus I.

The major part of the afternoon, after lunch in the General Mess, was taken up by an inspection of missiles on display. (These are listed, and some are pictured in official U.S. Navy photographs on the following two pages.)

IAS visitors missed, by only 3 days, arriving at the Center on the first birthday of PMR. It was established by the Secretary of the Navy on June 16 last year to provide range support for the Department of Defense and other designated government and nongovernment agencies engaged in guided missile, satellite, and space vehicle research, development, evaluation, and training programs. While under the military command of Admiral Monroe, it is under the management control of the Chief of the Bureau of Aeronautics.

Essentially, the PMR is composed of five different types of ranges:

The Extended Sea and Inland Range, which includes a sea area 250 by 500 nautical miles paralleling the California coastline and centered at Point Mugu and San Nicolas Island. This area is linked by air corridors to the closely controlled inland areas near Dugway, Utah, and Tonopah, Nev., where target and recovery zones are established.

The Ballistic Missile Range, which originates at the Naval Missile Facilities, Point Arguello, and at Vandenberg Air Force Base, provides a large support area with instrumentation for the evaluation of triservice training operations, and for handling IRBM and ICBM operations extending seaward to the central and western Pacific. ICBM's fired from these launching points will impact in various established areas of the central Pacific Ocean.

The Antimissile Missile Range, which is located in the western Pacific near a selected ICBM impact area. This range will support tests of antiballistic weapons against ICBM's.

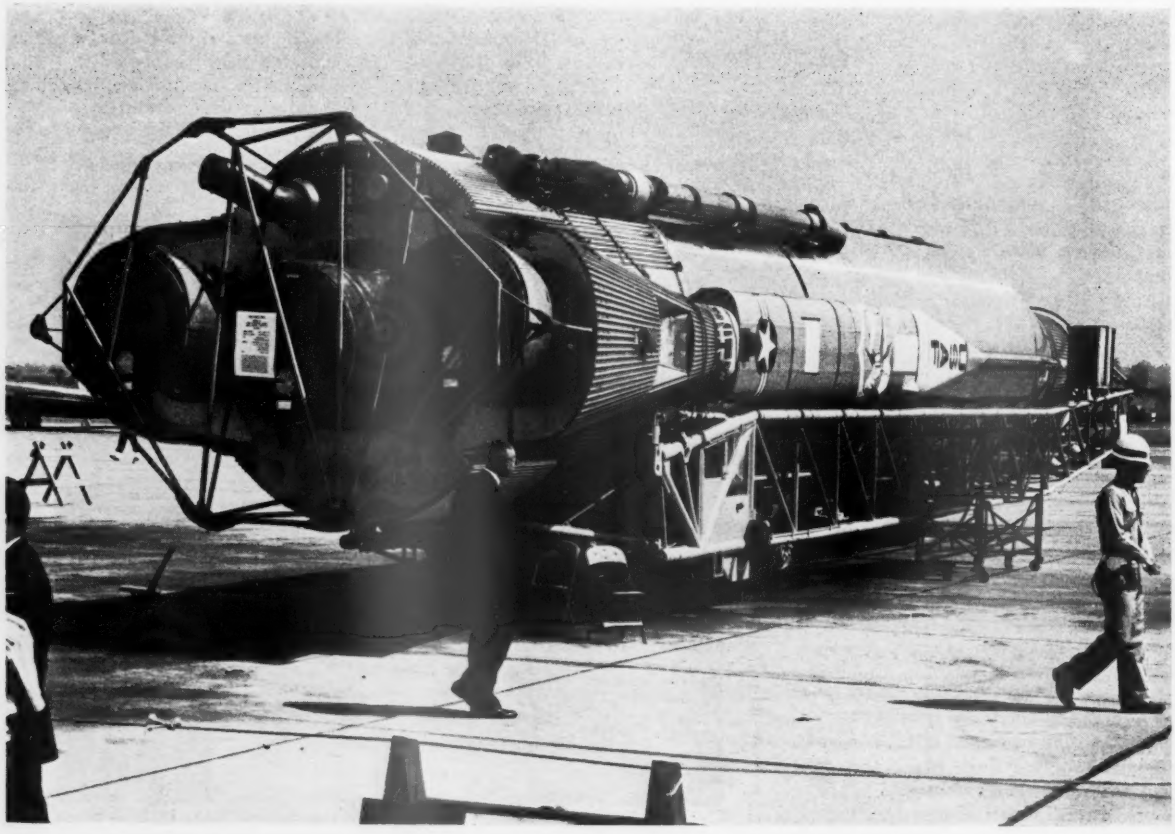
The Polar Orbit Range, which supplies facilities for launching satellites and other space vehicles into polar orbits. The range originates at Point Arguello, a large isolated area which can accommodate as large a booster as can now be imagined. This area provides maximum safety for nearby residents, as well as security for the operations themselves. The Point Arguello site also provides facilities for large-scale testing and training operations.

The Equatorial Orbit Range, which is centered near the equator. This will be used to support the launching of equatorial-orbit satellites.

Rear Admiral Jack P. Monroe, USN, Commander, Pacific Missile Range, welcomes IAS members to U.S. Naval Missile Center.

Official United States Navy Photograph

The official U.S. Navy photos on these pages indicate views prevailing at the IAS National Summer Meeting field trip to the U.S. Naval Missile Center, Point Mugu, Calif. *Above*, the camera peers down the missile display line. *At left* is a closeup of the Army's Hawk. The Air Force's Atlas is pictured *below*. *On the opposite page* is pictured a small segment of the 345 IAS members who attended the field trip as they were briefed on missile launchings. *At right*, the Air Force's Thor-Able held its own "open house" for visitors. (Note stairs providing an inspection of the missile's interior.)



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Missiles at Mugu

MISSILES ON DISPLAY

The following is a complete listing of missiles which were displayed for IAS visitors to the U.S. Naval Missile Center at Point Mugu.

Missile	*Contractor*
SD-2	Aerojet-General (formerly Rheem)
KDB-1	Beech
TALOS	Bendix
BOMARC	Boeing
REGULUS I	Chance Vought
REGULUS II	Chance Vought
ATLAS	Convair
TERRIER I	Convair
THOR	Douglas
NIKE-HERCULES	Douglas
NIKE-AJAX	Douglas
GENIE	Douglas
LITTLE JOHN	Emerson Electric
CORPORAL	Firestone
FALCON	Hughes
POLARIS	Lockheed
BULLPUP	Martin
QUAIL	McDonnell
ASROC	Minneapolis-Honeywell
SNARK	Northrop
HOUND DOG	North American
SIDEWINDER	NOTS
ZUNI	NOTS
OQ-19, Q-4	Radioplane
SPARROW III	Raytheon
HAWK	Raytheon
SWALLOW	Republic
FIREBEE	Ryan
SPARROW I	Sperry
TEAL	Temco

Looking over awards at the Northeastern Student Conference are *(left to right)* winners William J. Rae, Allister F. Fraser, Edmund C. Lary, Joseph S. Pratt, John P. Moran, and Albert R. George.

Record 117 Papers Read at Seven Regional Student Conferences

16 Reach Final Judging for Two Minta Martin National Awards to Be Announced at IAS Annual Meeting

ITHACA, Atlanta, Fort Worth, St. Louis, Washington, Detroit, and Los Angeles were the sites of this year's IAS Regional Student Conferences, held in the spring. For over 600 delegates who attended, they are now pleasant memories of papers read—a record 117—prizes awarded, and good fellowship.

Northeastern Conference

This year's conference was sponsored by Cornell's IAS Student Branch and the Institute's New York Section.

IAS President William Littlewood, a Cornell alumnus, presented the awards.

In the Doctorate Division, William J. Rae won first-place prize and Edmund C. Lary placed second; both are of Cornell University. In the Master's Division, award for first place went to Allister F. Fraser, Brown University, with second place going to John P. Moran, Cornell University. The Undergraduate Division first-place winner was Joseph S. Pratt, Virginia Polytechnic Institute, and second-place winner Albert R. George, Princeton University.

Southeastern Conference

The Atlanta Section as sponsor, and Mississippi State University as host, welcomed this year's delegates. Two days of technical sessions were concluded by the Awards Night Dinner.

In the Graduate Division, first-place prize went to E. Brian Pritchard, Virginia Polytechnic Institute, with the second-place award going to Edgar G. Miles, Mississippi State University. In the Undergraduate Division, the first-place award was presented to Charlie M. Jackson, Virginia Polytechnic Institute, with second- and third-place prizes going to Roland N. Bell and Peter R. Kurzhals, also V.P.I. students.

Southwestern Conference

One hundred and fifty delegates signed in at Fort Worth for this year's conference which was sponsored by the Texas Section.

Following his speech on "IAS and the Jet Space Age" at the Awards Dinner, IAS President William Littlewood presented Graduate and Undergraduate Awards.

In the Graduate Division, Donald L. Richardson, Texas A.&M., was first-place winner, and James E. Hayes, University of Oklahoma, was second-place winner. Third place was shared by coauthors B. D. Kowalsky and D. A. Pirie, both of Georgia Tech. First-place winner in the Undergraduate Division was David L. Kohlman, University of Kansas, and second-place winner was Ben L. Williams, Texas A.&M. Tying for third place were James A. Perkins, University of Wichita, and James W. Larsen, University of Colorado.

St. Louis Conference

IAS President William Littlewood was again on hand to present awards and deliver the main speech at the concluding banquet.

In the Graduate Division, first-place prize went to David L. Clingman, Purdue University, and second-place to Abraham H. Gallas, University of Kansas. In the Undergraduate Division, coauthors Francis J. Lavallee and August Verhoff, University of Notre Dame, were first-place winners; second- and third-place prizes went to Grant B. Skelton, Northwestern University, and Jon Gnagy, University of Kansas, respectively. Also, Merit Awards were given to the following: John J. Lacey, Parks College; Jon Strauss, University of Wisconsin; and Donald E. Wall, University of Kansas.

Middle-Atlantic Conference

Catholic University was sponsor and host to 50 students and faculty advisers. Fifteen papers were presented.

IAS President William Littlewood, making his fourth appearance at a 1959 Student Conference, was speaker at the Award Dinner. Before discussing some of the problems facing the aviation industry with the advent of commercial jet service, Mr. Littlewood presented the awards.

In the Doctorate Division, the award went to Abdul Khaliq Azad, Catholic University. In the Master's Division, prizes were collected by John W. Whitehurst, also an engineering student at Catholic University, who placed first,

Shown with their awards at the Southeastern Student Conference are *(left to right)* winners Roland N. Bell, Charlie M. Jackson, E. Brian Pritchard, Peter R. Kurzhals, and Edgar G. Miles.

XUM

and Thomas Finch, University of Maryland, who took second-place honors. In the Undergraduate Division, Anthony J. Culotta and Thomas P. Kossiarus, both of the University of Maryland, coauthored the prize-winning paper. Second- and third-place prizes went to William G. Dove, University of Virginia, and Harry Defarrari, Catholic University, respectively.

Detroit Conference

The Detroit Section and the University of Detroit Student Branch were joint sponsors of the conference.

Detroit Section Chairman Richard Chute presented the awards. In the Undergraduate Division, first place went to Henry C. Kowalski, Wayne State. Second- and third-place awards were presented to Charles Meldrum and Dale Calkins respectively, both engineering students at the University of Detroit.

West Coast Conference

Along with TV coverage, the 9th Annual West Coast Student Conference opened under the chairmanship of Dr. E. R. van Driest, Director of Aero Space Laboratories of the Missile Division of North American Aviation, Inc. Total student registration was 156, plus faculty advisers, judges, and industry representatives.

The Awards Night Dinner had as Honorary Chairman Clarence L. ("Kelly") Johnson of Lockheed, a Vice-President of the IAS. Guest speaker was Dr. Manfred Eimer, who is Assistant Chief of Research Analysis at Jet Propulsion Laboratory. Dr. Eimer showed a film of the March, 1959, firing of the Pioneer IV moon probe.

In the Doctorate Division, first place was won by Ronald Stearman, California Institute of Technology, and the second-place award was given to Richard A. Schapery, also of California Institute of Technology.

In the Master's Division, first place went to a paper coauthored by R. E. Adler and C. J. Tetrick, U.S. Naval Postgraduate School, Monterey. Second and third places were won by H. V. Sathyanarayana, Stanford University, and T. C. Gunning, U.S. Naval Postgraduate School, Monterey.

The Undergraduate Division's first prize was won by Carl A. Zierman, University of California; second-place prize by Lee Murphy, Northrop Institute of Technology; and third-place prize by James E. Terry, California State Polytechnic College.

The Minta Martin Aeronautical Student Fund, established by the late Glenn L. Martin in honor of his mother, sponsors the conferences and cash awards. From among the first-prize graduate and undergraduate papers at all seven conferences, one national award winner will be chosen from each division by a board of eminent scientists and engineers. The winners receive engraved plaques for outstanding engineering achievement, duplicates of which are presented to their universities. Presentation of these national awards will be made at the IAS 28th Annual Meeting, January, 1960.

Award winners line up at the Southwestern Student Conference. *Left to right* are B. D. Kowalsky, D. A. Pirie, James A. Perkins, David L. Kohlman, James W. Larsen, Ben L. Williams, James E. Hayes, and Donald L. Richardsor.

Shown (*left to right*) at the St. Louis Student Conference are Chairman B. C. Boulton and award winners Abraham H. Gallas, Jon Gnagy, David L. Clingman, Francis J. Lavallee, August Verhoff, Grant B. Skelton, and Anthony W. Harris in charge of IAS Student Activities.

(*Left*) IAS President William Littlewood congratulates award winner John W. Whitehurst at the Middle Atlantic Student Conference. (*Right*) Award winner Henry C. Kowalski presents his paper at the Detroit Student Conference.

Dr. E. R. van Driest (*left*), Chairman of the West Coast Student Conference, and Clarence Johnson (*right*), Honorary Chairman, look on as Carl A. Zierman accepts his award.

XUM

IAS News

Program for Durand Centennial Conference

The Durand Centennial Conference on Aeronautics and Astronautics, in honor of the 100th anniversary of the birth of William Frederick Durand, HFIAS, is being held August 5–8 at Stanford University, California. The IAS is one of six sponsoring societies.

A tentative program of lectures to be given at the Conference is as follows:

August 5—"Contributions of William Frederick Durand to Aeronautics" by Hugh L. Dryden, NASA; "Similarity Solutions of Hydrodynamic Problems" by Sir Geoffrey Taylor, Cambridge, England; "Frontiers of Flight Structures Design" by Richard R. Heldenfels, NASA; "Transient Temperatures and Thermal Vibrations in Space Structures" by Luigi Broglio, Instituto di Costruzioni Aeronautiche, Rome, Italy; "New Developments in the Nonlinear Theories of Buckling of Thin Cylindrical Shells" by R. H. Thielemann, Deutsche Versuchsanstalt fur Luftfahrt E. V., Mulheim (Ruhr), Germany.

August 6—"Recent Trends in the Mechanics of Highly Rarefied Gases" by Gordon N. Patterson, University of Toronto, Canada; "A Study of Effusive Flow" by Hans W. Liepmann, California Institute of Technology; "A New Look at Transition" by Leslie S. G. Kovasznay, The Johns Hopkins University. Other lectures are still to be arranged.

Joel M. Jacobson (AF) has been elected President of Aircraft Armaments, Inc. Mr. Jacobson was a key organizer of the company in 1950 and has served as Vice-President and General Manager since then.

August 7—"Creep Buckling of Plane Frameworks" by Jan Hult, The Royal Institute of Technology, Stockholm, Sweden; "Thermodynamic Foundations of the Theory of Deformation" by J. F. Besseling, Stanford University; "Leading-Edge Structures for Cooling by Radiation" by Wilfred H. Dukes, Bell Aircraft Corp.; "Magnetogasdynamic Problems From the Point of View of the Kinetic Theory" by J. M. Burgers, University of Maryland; "Plasma Dynamics" by Francis Clauser, The Johns Hopkins University; "Some Heat-Transfer Problems in Hypersonic Flow" by Antonio Ferri, Polytechnic Institute of Brooklyn.

August 8—"On the Motion and Ablation of Meteoric Bodies" by H. Julian Allen, NASA; "Precision Orbits and Observation Reduction" by Samuel Herrick, University of California at Los Angeles; "The Advent of Astronautics" by Wolfgang B. Klemperer, Douglas Aircraft Co., Inc.

All the lectures will be assembled in a commemorative volume which will be published after the Conference. Any further information should be obtained from Dr. Nicholas J. Hoff, Head, Division of Aeronautical Engineering, Stanford University, Stanford, Calif.

IAS Director Serves on Flight Safety Foundation Board

S. Paul Johnston, Director of the IAS, was elected a member of the Board of Governors of the Flight Safety Foundation, Inc.

The Flight Safety Foundation is an independent nonprofit organization working to promote greater safety in all forms of flight on a worldwide basis. It is supported by 39 American flag and foreign airlines and more than 250 other corporations and organizations.

Honorary Degrees to Two Members

Honorary degrees were conferred on two members by Adelphi College at its sixty-third annual commencement exercises held June 10.

Dr. Hugh L. Dryden (HF, HM), Deputy Administrator of the NASA, received the degree of Doctor of Laws; Willy Ley (M), editor and author, received the degree of Doctor of Humane Letters.

Necrology

Karl H. Falk

Karl H. Falk died on May 11 at the age of 61. He had been associated for many years with Hamilton Standard Division of United Aircraft, doing design and stress analysis work on propeller blades and accessories.

Mr. Falk was author of the *Aircraft Propeller Handbook*, published in 1937 and revised in 1943.

He received his engineering degree in 1924 from the Altenburg Polytechnical Institute, Germany.

Comdr. Peter Rippa

Commander Peter Rippa, USN (M), it has been learned, was killed in a flight accident on March 24. He had been a naval aviator for 16 years and was an operations analysis officer on the staff of the Commander of the First Fleet.

He had received a B.S. degree in Operations Analysis from the University of Tampa and an M.S. degree from the U.S. Naval Postgraduate School.

Commander Rippa was holder of the Air Medal and the Presidential Unit Citation; he had four battle stars from the Asian Pacific combat area.

He was a member of the Operations Research Society of America and the U.S. Naval Institute.

Lt. Col. Melvin E. Williamson

The Institute has received news of the death of Lt. Col. Melvin Edward Williamson (M) on February 15. Colonel Williamson was Chief of the Radio-TV Branch, Office of Armed Forces Information & Education, Department of Defense, Washington, D.C.

Before joining the Armed Services in 1942, he was associated with Radio Station KMPC in Beverly Hills, Calif., as a writer and director of general programs. He was later associated, in the same capacity, with Hixson-Odonell Advertising Agency, Los Angeles, and Russell M. Seeds Co., Chicago, where he was director of "Wings of Destiny."

After serving as Assistant Group Officer and Photographic Officer at Langley Field, he was transferred to the Radio Branch of the Bureau of Public Relations of the War Department in 1943. Writing on aviation subjects, he also acted as technical adviser to radio and film writers.

He attended Riverside Junior College in California and the University of Texas.

News of Members

Milton B. Ames, Jr. (F), has been appointed Assistant Director of Aeronautical and Space Research for the NASA. He will be responsible for organizing and coordinating NASA research programs in the aeronautics and mechanics of flight vehicles, including airplanes, missiles, and spacecraft. He was formerly Chief of the Aerodynamics and Flight Mechanics Division of the NASA.

Dr. Samuel B. Batdorf (AF) has been appointed Director of Research for the Lockheed Electronics and Avionics Division, Lockheed Aircraft Corp. On leave since March, 1958, to accept a Pentagon assignment with ARPA, he formerly served as Assistant Director of Research and Head of the Electronics Division of Lockheed Missiles and Space Division.

Arden F. Boyd (A) has been named an Engineering Specialist in Dynamic Analysis of Flight Control Systems for

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AN ENTIRELY NEW CONCEPT IN PRESSURIZATION AND COOLING . . . **A** *Nose cone cooling,* **B** *Cabin pressurization and cooling,* **C** *Suit pressurization and cooling,* **D** *System control,* **E** *Heat exchangers,* **F** *Electronic bay (cooling and inerting),* **G** *Supply valve,* **H** *Nitrogen relief valve,* **I** *Liquid nitrogen storage tank,* **J** *Liquid nitrogen vent valve,* **K** *Liquid nitrogen filler valve,* **L** *Helium vent and buildup valve,* **M** *2-stage helium regulator, 4400-65 psi,* **N** *High pressure helium storage,* **O** *High pressure helium filler valve,* **P** *Helium relief valve.*

• *The AiResearch Pressurization And Air Conditioning System* in North American's X-15 is a radical departure from normal pressurization and cooling techniques, also pioneered by AiResearch, which up to now have utilized outside air surrounding the aircraft. When the X-15 manned spacecraft climbs into space beyond the earth's atmosphere, it will carry its own atmosphere in the form of liquid nitrogen dispensed through a self-sufficient AiResearch pressurization and air conditioning system for the pilot and vital equipment.

X-15 applications include: pressurizing and ventilating the cockpit and the pilot's flight suit inside of which he breathes pure oxygen; cooling and pressurizing electronic equipment and inerting its environmental atmosphere; cooling the plane's nose cone; and, operating pneumatic equipment.

High pressure helium gas is metered to a flexible expulsion bladder forcing nitrogen out of the storage tank, insuring a normal flow at all times.

From the B-29 to the modern jet airliner and now the X-15, AiResearch pressurization and cooling of these history-making aircraft exemplify the company's continued world leadership in the pioneering and advanced development of pressurization and refrigeration systems for high altitude, high speed flight. Your inquiries are invited.

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Summers Gyroscope Co. He was formerly an Aerodynamics Engineer in the Advanced Design Section at North American Aviation, Inc.

Dr. Robert G. Brault (M) has been named Head of Callery Chemical Company's newly established West Coast office in Los Angeles. The office will provide expanded service for customers of Callery's Defense Products Department.

Gerald A. Busch (AF), formerly Senior Economist in the Corporate Development Planning Department, has been promoted to Director of Market Research, Lockheed Aircraft Corp.

George S. Cherniak (M) has been named Director of Space Technology Laboratories' Flight Test Operations at the Atlantic Missile Range, Cape Canaveral, Fla. As Director of Flight Test Operations, he has responsibility for technical direction and coordination of flight-test phases for the Atlas, Titan, and Minuteman ICBM's, the Thor IRBM, and related space projects. He was formerly Head of STL's Atlas Project Office, Cape Canaveral.

Arthur N. Corner (M) has joined the Technical Staff of the Ramo-Wooldridge Division of Thompson Ramo Wooldridge Inc. He was formerly Manager of Missile Test Equipment at Farnsworth Electronics Division of International Telephone and Telegraph.

Richard V. Davis (M) has been promoted to Manager of Applications Engineering, Jet Engine Department, at General Electric Co. in Evendale, Ohio. Mr. Davis was formerly Manager of Aircraft Equipment Sales in G-E's Seattle sales office.

Richard B. Dittmar (M) has been elected a Vice-President of The Ralph M. Parsons Co. He is Manager of Business Development for the architect-engineering division.

Bernard J. Driscoll (M) has been appointed to the newly created position of Vice-President & General Manager, General Applied Science Laboratories, Inc. Mr. Driscoll was formerly an Associate Director of a special USAF study at the National Academy of Sciences—National Research Council.

Samuel E. Eastman (A) has been named Director of the Washington Research Office of Technical Operations, Inc. Prior to this, he was Assistant Director of their Burlington facilities.

Brig. Gen. Harold R. Harris, USAF (Ret.) (F), President of Aviation Financial Services, Inc., has been elected Chairman of the Board of Governors and Executive Committee of the Flight Safety Foundation.

Dr. Nicholas J. Hoff (F), Head of the Department of Aeronautical Engineering at Stanford University, has been appointed Chairman of the Ship Structural Design Committee of the National Academy of Sciences—National Research Council.

Richard L. Oblinger (M) has been named Chief Applications Engineer for Controls and Accessories in The Marquardt Corp.'s Controls and Accessories Division. He was formerly in Marquardt's Customer Relations Department.

George A. Squires (M), formerly Project Engineer at Ketco Incorporated, has been named Technical Manager at The Hartman Technical Service, Cincinnati, Ohio.

Wendell W. Suydam (M) has been named Manager of the Overhaul and Repair Department of Hamilton Standard, division of United Aircraft Corp. He joined Hamilton Standard in December, 1958, as Assistant Purchasing Agent.

Orvil S. Tuttle (A), inventor of a new type of metal sandwich called Pelcor, has been appointed Technical Director of Monogram Precision Industries, Inc., holders of exclusive rights to engineer, manufacture, and market Pelcor. One of the original developers of honeycomb structures, Mr. Tuttle will supervise structures activity in his new post.

Jan A. van der Bliek (M), formerly Assistant Research Officer at the High Speed Aerodynamics Laboratory of the National Research Council, has been appointed a Project Engineer in the Hypervelocity Branch of the Gas Dynamics Facility, ARO, Inc.

Milton D. Van Dyke (A), formerly an Aeronautical Research Scientist at the Ames Research Center, NASA, has been appointed Professor of Aeronautical Engineering at Stanford University. Professor Van Dyke is returning this fall from Paris after spending a year as Visiting Professor at the Sorbonne.

Herbert K. Weiss (AF) has joined the Weapon Systems Division of Aeronutronic Systems, Inc., as Manager of Advanced Systems Development. He was formerly Chief of the Weapon Systems Analysis Department, Northrop Corp.

Robert O. Wickersham (M), formerly Assistant Program Director, has been promoted to Director of the Program Management Staff, Systems Engineering Division, of Space Technology Laboratories, Inc.

Joseph Yamron (M), formerly Section Head of the Flight Control System Group at M.I.T., has joined Hamilton Standard, division of United Aircraft Corp., as Project Engineer in charge of Flight Control Systems.

IAS News — Corporate Member News

• **Aerojet-General Corp.** has appointed Victor E. Caffee as Assistant Director of Materiel.

• **American Airlines, Inc.,** has elected George A. Spater an Executive Vice-President. He will serve as General Counsel, heading up a small, internal legal department. Richard H. Brooks has been appointed Director of Facilities in the New York offices.

• **Bendix Aviation Corp.** has appointed Forrest L. Dunbar, formerly Director of Industrial Relations at the Bendix Products Division, and D. M. Heller, formerly Assistant General Manager, Bendix Missiles Section, to the staff of George E. Stoll, Vice-President and Group Executive. Mr. Dunbar has been named Executive Assistant.

• **Bulova Research and Development Laboratories, Inc.,** has named Mark E. Lemelman to the newly created post of Project Manager for its new direct-reading servodriven aircraft altimeter.

• **Chicago Aerial Industries** has acquired additional office facilities as a continuing part of an expansion program which will culminate next year in the construction of a new engineering and production facility near Barrington, Ill.

• **Cornell Aeronautical Laboratory, Inc.,** has announced creation of a new Hypersonic Tunnel Department which will be headed by King D. Bird, formerly head of the Transonic Tunnel Department. James F. Martin has been named Assistant Head of the new Department. John P. Andes has been promoted from Assistant Head to Head of the Transonic Tunnel Department, and Ray W. Cotter has been named Assistant Head.

• **Douglas Aircraft Co., Inc.,** recently dedicated its new Aerophysics Laboratory, El Segundo, which is capable of testing aircraft and missile models at simulated speeds exceeding Mach 10.

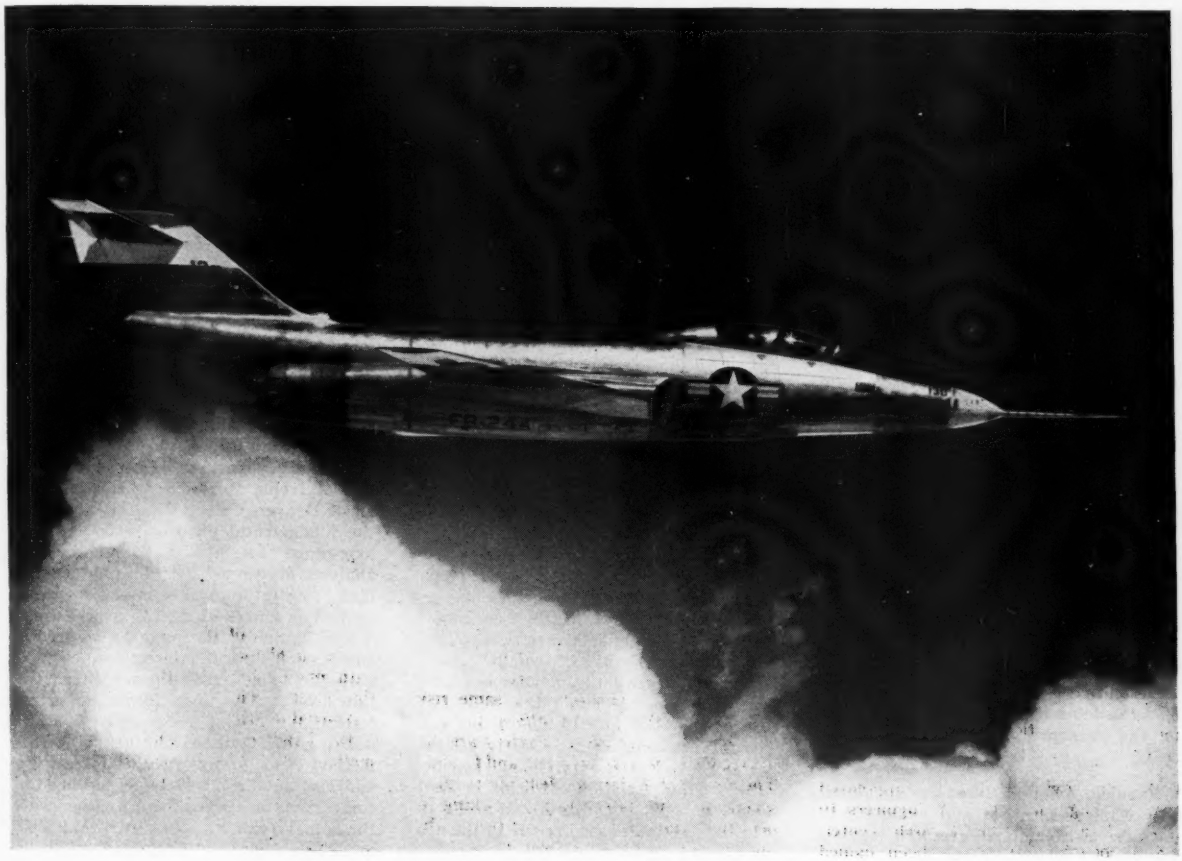
• **The Garrett Corp.** has named Arthur Link as a Consultant. He becomes a member of the corporate research group and corporate policy group, advising on missile and electronics projects. . . . AiResearch Manufacturing Division in Los Angeles has appointed James V. Crawford to the position of Chief Engineer and Norman M. Brown as Assistant Chief Engineer. In Phoenix, Dr. Helmut Schelp was named Chief Engineer and Carl Paul became Assistant Chief Engineer. C. F. Blanking was named Engineering Manager.

• **General Dynamics Corp.** . . . Convair has appointed Conrad Kunze Assistant to the Executive Vice-President. . . . Stromberg Carlson has expanded its Military Products marketing activities for its Special Products Division and has appointed William F. Rhodes as Manager, Military Products. The Electronics Division has named David Y. Keim Chief Engineer—Military Products.

• **General Electric Co.** . . . Flight Propulsion Division has appointed George H. Ward as Manager—Applications, J85 Project, Small Aircraft Engine Department.

• **General Precision Equipment Corp.** . . . Librascope, Inc., has started construction on a major addition to its Glendale headquarters. The new 85,000-sq.ft. facility will provide additional production space for the assembly of electronic computers and associated equipment.

GENERAL MOTORS HEXES HEAT ON THE VOODOO!



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HARRISON OIL COOLERS CONTROL VITAL TEMPERATURES ON McDONNELL F-101B VOODOO—POWERFUL NEW INTERCEPTOR!

Like magic, the new Voodoo F-101B streaks to its target with an amazing combination of speed and long range. Such outstanding performance demands dependable operating temperatures *every second.* That's why rugged and reliable Harrison heat exchangers were selected to cool the engine oil on this supersonic all-weather interceptor of the Air Defense Command. Built and backed by General Motors, Harrison heat-transfer equipment provides dependable temperature control—in every type of industry, every line of defense. Harrison, with over 47 years in the heat-exchanger field, is your assurance of top quality in product and performance. If you have a cooling problem, look to Harrison for the answer.

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• **Lear, Inc.** . . . Grand Rapids Division has been reorganized into two separate general operating divisions—the Instrument Division, with J. M. Walsh as General Manager, and the Electro-Mechanical Division, with T. K. Greenlee as General Manager. The Instrument Division will move into the new $5 million plant at the Kent County Airport near Grand Rapids, Mich. The Electro-Mechanical Division will remain in Grand Rapids.

• **Lockheed Aircraft Corp.** has announced agreement with Stavid Engineering, Inc., of Plainfield, N.J., to combine the two firms. Stavid specializes in military electronics. . . . Georgia Division has promoted C. H. Roha to Assistant Director of Materiel and announced the appointment of Robert Murph Jones as Assistant Manager of Nuclear Products.

• **Minneapolis-Honeywell Regulator Co.** . . . Aeronautical Division has named Kenneth H. DeRoche as Contract Manager and Samuel H. Cantwell as Manager of Administration for its Missile Development Laboratory.

• **North American Aviation, Inc.,** has elected Wilbert H. Yahn a Vice-President and appointed him General Manager of the Columbus, Ohio, Division. . . . Missile Division has appointed James Y. Cunningham as Factory Manager.

• **Northrop Corp.** has elected Thomas V. Jones as President to succeed Whitley C. Collins who died suddenly. . . . Nortronics Division has announced acquisition of a 50-acre site on the Palos Verdes peninsula for the construction of a major research center.

• **Republic Aviation Corp.** has appointed four leading scientists and engineers to its new astronautical research center. Dr. Robert W. Perry has been named Head of the Re-Entry Simulation Laboratory, and Dr. Samuel Korman will head the Materials Development Laboratory. Associated with Dr. Korman in the Materials Laboratory are Dr. Robert P. Bastian as Chief Chemist and Dr. Stanley Zirinsky as Chief Metallurgist.

• **Space Technology Laboratories, Inc.,** has appointed Dr. Paul Dergarabedian as Manager and Abraham Fiul as Associate Manager of the Systems Design and Analysis Department. Arnold R. Anchordoguy has been named Program Director for the Thor Weapon System.

• **Sperry Gyroscope Co., Division of Sperry Rand Corp.,** has announced the promotion of Samuel C. Yeaton to Vice-President and Director of Patents. Appointment of William F. Horn as Manager of West Coast Field Operations was also announced.

• **Thiokol Chemical Corp.** has appointed Dr. W. M. Mebane, formerly Manager of the Redstone Division, as Secretary of the corporation.

• **Trans World Airlines** was presented with a certificate of appreciation by the U.S. Army for "patriotic civilian service." The award was in recognition of a course of instruction in aviation maintenance management presented by TWA during the past year.

• **United Aircraft Corp.** . . . Norden Division has appointed Samuel B. Sherwin as Manager of the Ketay Department. Wladimir Reichel, Chief of Basic Design, has assumed the additional responsibilities of Engineering Manager of the Ketay Department.

IAS News — IAS Sections

Chicago Section

Navy Air Chief Discusses Air Training

The methods used in selection and training of candidates for naval aviation were discussed by **Rear Adm. J. M. Carson, USN,** Chief of Naval Air Basic Training, Pensacola Naval Air Station, Florida, at the May 22 meeting held at the U.S. Naval Air Station, Glenview, Ill.

Admiral Carson told members that human quality control is used as a means of selecting student aviators, and is similar to the quality control methods of industry. The real search starts in the fleet; in viewing pilot-error accidents, things can be found which might have been located through quality control checks in primary flight training. Admiral Carson spoke of the constant study of each cadet throughout his training as part of a program of checking on known controls to minimize dangers to pilots. In discussing the flight safety record, he said that the military aviator in peacetime is in approximately the same risk category as the ground officer in war. The three familiar areas in safety are the "three F's"—fear, frustration, and fatigue. The School of Aviation Medicine in Pensacola, he said, is constantly working to help the aviator adapt himself to the abnormal environment in which he works.

Prior to the meeting, a reception honoring Admiral Carson and the newly elected section officers was held at the Officer's Club. Chicago Aerial Industries, IAS Corporate Member, and Cook Electric Co. were cohosts for the event.

The new officers are Joseph Islinger, Chairman; Paul Pederson, Vice-Chairman; Miles Mraz, Secretary; Bert Engstrom, Treasurer; and Miss Rose Minkin, Historian.

Cleveland-Akron Section

Weather Expert Is May Speaker

Speaker at the May 25 meeting was **Dr. Irving P. Krick,** President of the American Institute of Aerological Research, Water Resources Development Corp., and of Irving P. Krick Associates, Inc., all of Denver, Colo. Dr. Krick outlined the fundamental philosophy used in his long-range forecasting techniques—the analysis of wave forms to produce the high-pressure and low-pressure areas, commonly known in meteorological work. The definition of the wave forms used is based on historical information, coupled with predictable conditions such as the tide levels. The wave forms are extra-terrestrial in origin.

Dr. Krick reviewed the history of his method of long-range weather forecasting and also gave some facts concerning the comparison of his predicted weather with the actual weather. He stated that their predictions have been correct to about 80 per cent of variability from normal, and that this accuracy can be obtained on weather prediction of a year or more in

Rear Adm. J. M. Carson, USN, Chief of Naval Air Basic Training, Pensacola, Fla., who was speaker at the Chicago Section's May 22 meeting at the U.S. Naval Air Station in Glenview, Ill., is flanked by IAS members Fred T. Sonne (A), President, and Dick Schram (AF), Director of Public Relations, Chicago Aerial Industries. Prior to the meeting they visited the static display in the Naval Air Station maintenance hangar, where the Navy's newest jet trainer, the North American T2J-1, was displayed. Also on exhibit were the Lockheed T2V-1 "Seastar" carrier-based jet trainer (seen in background), and the Grumman F9F-8T jet trainer, equipped with missile launching gear.

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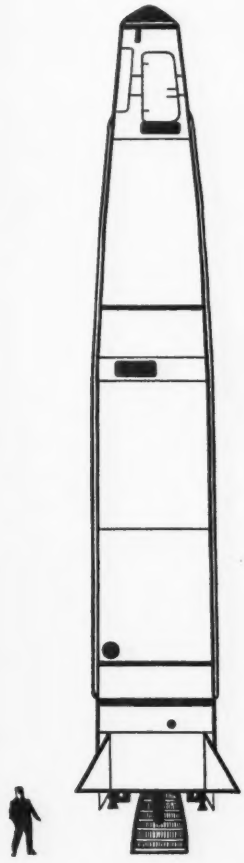
The man:

. . . a launch-control specialist in a *Thor* SAC squadron. His instruments report each automatic step in the launching procedure of the big IRBM. U.S. Air Force and Royal Air Force missilemen are receiving *Thor* training side-by-side . . . have readied and fired these missiles within a 20-minute count-down.

The missions:

. . . are many—because of the Douglas *Thor's* versatility. As a highly mobile weapon with atomic capability, it sternly warns potential enemies against aggression. As a powerful and reliable booster, it is playing a leading role in our exploration of outer space with satellites and probes.



The missile:

. . . can destroy targets as far as 1500 miles away within minutes after hostile action is detected. Douglas *Thor* missiles were the first intermediate range ballistic missiles to be deployed overseas. The United Kingdom has announced the delivery of the first *Thors*, for operation by Royal Air Force personnel.

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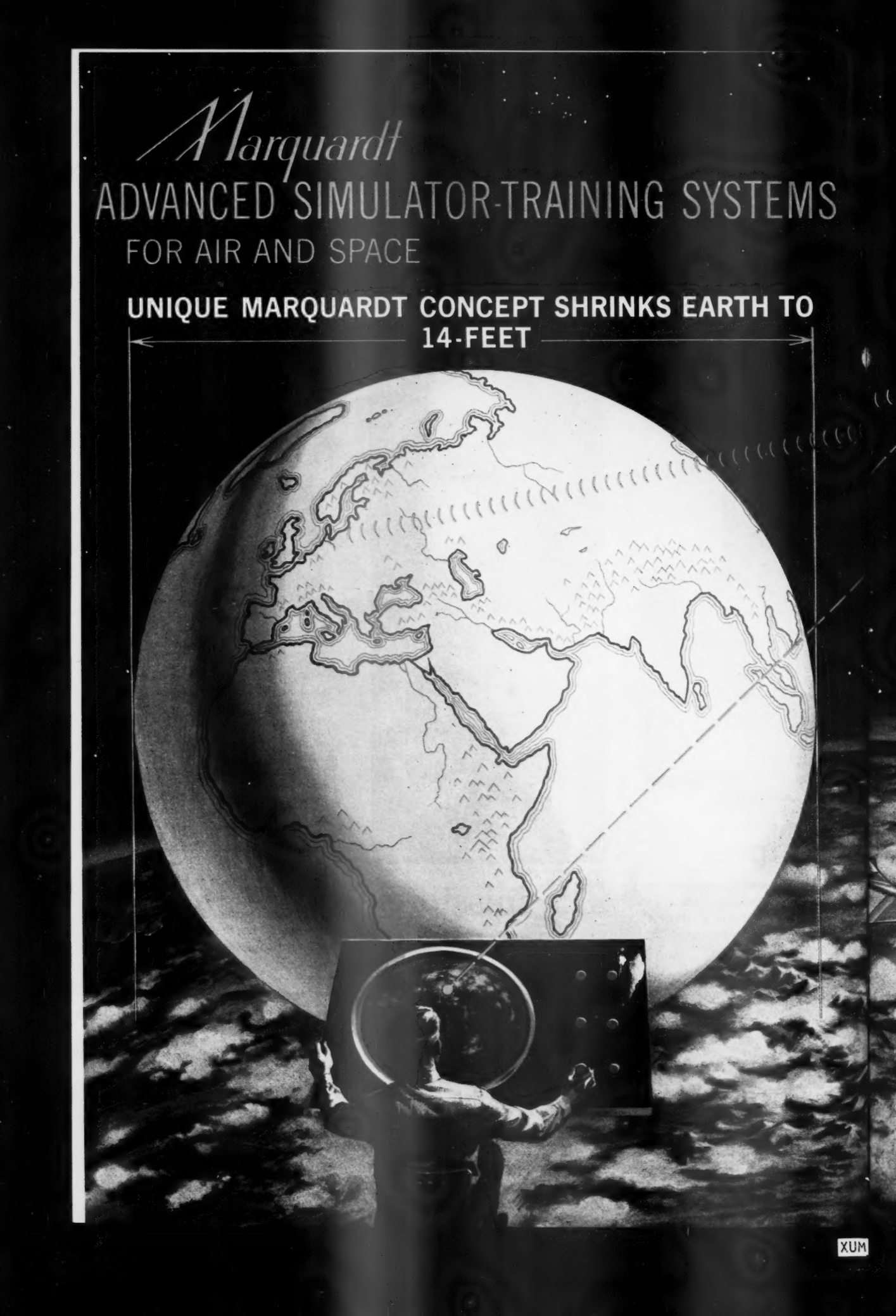
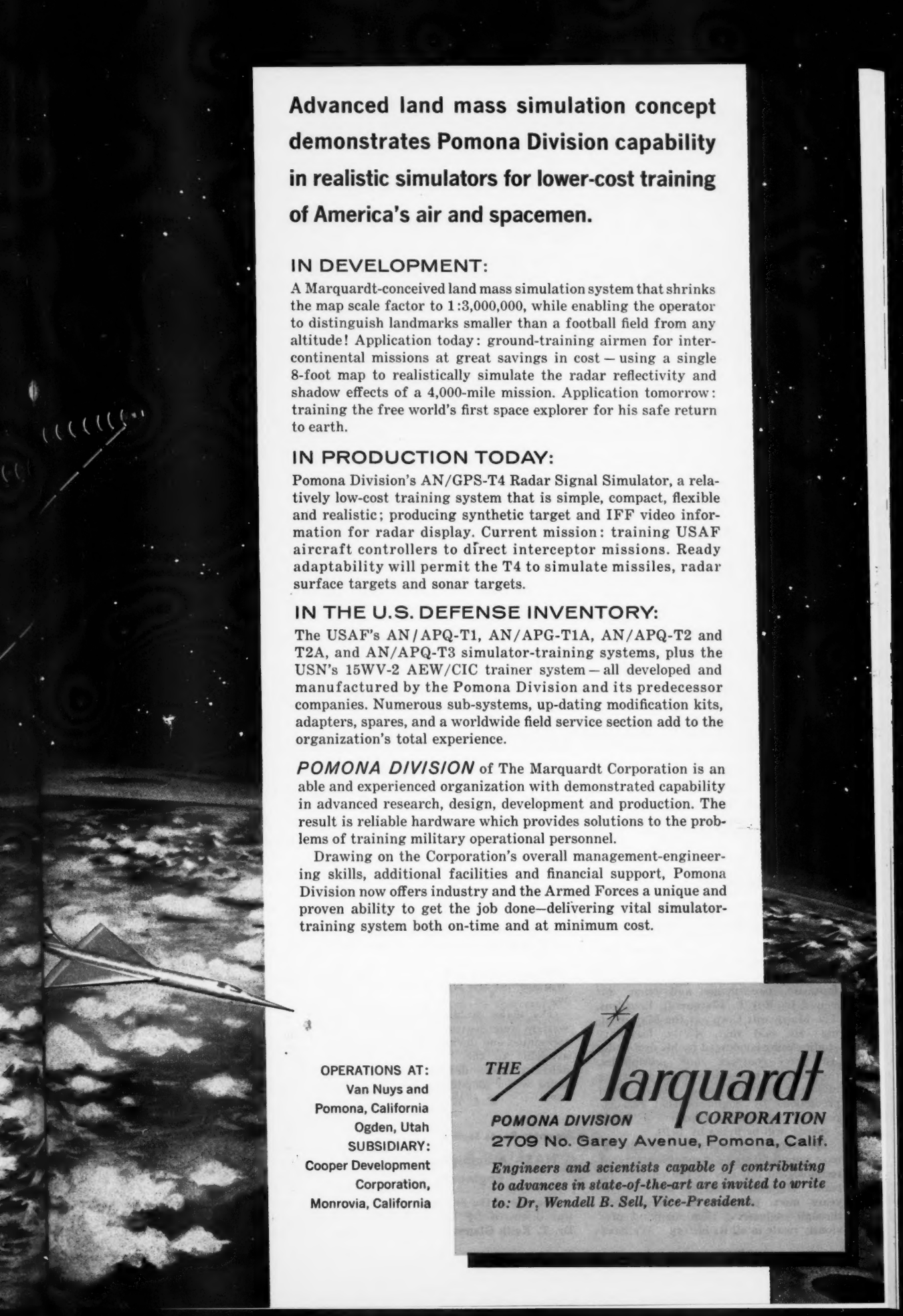

Marquardt
ADVANCED SIMULATOR-TRAINING SYSTEMS
FOR AIR AND SPACE
UNIQUE MARQUARDT CONCEPT SHRINKS EARTH TO 14-FEET
XUM



Advanced land mass simulation concept demonstrates Pomona Division capability in realistic simulators for lower-cost training of America's air and spacemen.

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A Marquardt-conceived land mass simulation system that shrinks the map scale factor to 1:3,000,000, while enabling the operator to distinguish landmarks smaller than a football field from any altitude! Application today: ground-training airmen for intercontinental missions at great savings in cost — using a single 8-foot map to realistically simulate the radar reflectivity and shadow effects of a 4,000-mile mission. Application tomorrow: training the free world's first space explorer for his safe return to earth.

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Engineers and scientists capable of contributing to advances in state-of-the-art are invited to write to: Dr. Wendell B. Sell, Vice-President.

XUM

At the May 14 meeting of the New York Section, Igor I. Sikorsky (F) (*in cap*) answered questions on the operations of the S-60 crane helicopter. He later spoke at the dinner portion of the meeting which was held at the Sikorsky plant in Stratford, Conn. Members who attended toured production and experimental areas in the plant and also witnessed flights of the single-engine Sikorsky S-62 turbocopter and the Army version of the Sikorsky S-56. In photo at right (*left to right*), Kadislav Kadlec (M) of Avien, Edward R. Luff (A) of Kaman Aircraft, and W. L. Emerson (M) of Hexcel Products, Inc., inspect the nose section of the Army version of the S-56.

advance. He stated that their present techniques permit them to predict the weather as much as 4 years in advance.

▶ At the April meeting, **Dr. Paul R. Annear** from Baldwin-Wallace College gave a talk on **"Observational and Computational Tracking of Sputnik III."** Dr. Annear discussed the techniques that were used at Cape Canaveral in obtaining tracking and other information on Sputnik III. He also showed some interesting color slides of the area in and around Cape Canaveral.

▶ At a joint February meeting of the IAS and ARS, **Dr. J. A. Van Allen,** State University of Iowa, spoke on **"Trapped Corpusculor Radiation Around the Earth."** Dr. Van Allen discussed primarily the results of the Explorer series of satellites, with main emphasis on cosmic ray analysis. He explained the instrumentation used on each Explorer and why it was used, and gave a quick summary of the analysis of the data to date.

C. J. PENNIG, *Secretary*

Great Salt Lake Section

Roy Marquardt Optimistic About Ram-Jet Engines

A prediction that ram-jet engines soon may be wedded to nuclear energy and exotic fuels to produce power plants of fantastic performance and range was voiced by **Roy E. Marquardt,** President, The Marquardt Corp., at the May meeting. He said that, if the feasibility studies being conducted by his firm under Air Force contract show possibilities, the result will be a supersonic air-breathing missile of unlimited range. He also cited predictions by engineers that ram-jet-powered transports, capable of Mach 7 speeds, will be flying by 1970.

Mr. Marquardt said that probably the most important single element in the rapid technological advance is the engineering team. He noted that in the past 30 years more progress has been made through engineering than mankind previously made in all its history. We have reached a point in time where the fact that science knows no boundaries must be put to a test.

He cited the impact of technological advances on the Intermountain Area with the establishment of new electronics firms, advanced propulsion system producers, and allied industries needed to support these operations.

Mr. Marquardt was optimistic about the future for ram-jet engines. While the power plant is useless when standing still, once it is driven through the air at the required speed for operation, it operates more efficiently the higher and faster it goes. With an eye to the future, he said that Marquardt Corp. launched a major expansion and diversification program within the last year.

Hagerstown Section

Classified Meeting on ASW

A major problem of the United States is to protect the shipping lanes to the NATO nations and to keep them open as supply routes. To accomplish this, a highly effective means of detecting enemy submarines is necessary, according to **Comdr. Robert L. Dahllof, USN,** of the ASW Readiness Executive's Office, Office of the Chief of Naval Operations, in a talk on **"Developments in Antisubmarine Warfare"** at the May 12 classified meeting.

The major problems of antisubmarine warfare were discussed, and some of the techniques and devices that are currently available to the Navy for submarine detection were described, followed by slides which amplified the presentation.

E. L. HARKLEROAD, *Secretary*

Hampton Roads Section

NASA Administrator Discusses Engineer's Role

The role of the engineer in the sciences was discussed by NASA Administrator **Dr. T. Keith Glennan** at a joint meeting of the IAS, ASME, and Engineers Club; over 600 members and guests attended.

Dr. Glennan noted that a large part of the aeronautical problems had been solved by engineers; however, he said, when a solution was particularly noteworthy, the engineer was referred to as a scientist and his work as a "scientific achievement."

Without detracting from the high level of the scientist, Dr. Glennan said that the role of the engineer should not be discounted, pointing out that engineers will perform and direct most of the research and will be responsible for all operations involved in space research. He said there was a need for more emphasis on the merits of engineering as a profession. He noted that it was not by accident that all the men chosen as Astronauts for the Mercury project had at least a B.S. degree in Engineering.

JOHN M. EGGLESTON, *Secretary*

Rocky Mountain Section

Schriever Is Speaker at USAF Academy Meeting

Introduction of liquid hydrogen, at a temperature near absolute zero, was disclosed as a new propellant fuel by **Lt. Gen. B. A. Schriever** before his talk on **"Military Leadership in the Space Age"** at the May 11 meeting, held at the U.S. Air Force Academy, Colorado Springs, Colo.

In his talk, General Schriever noted the close relationship between the military officer, engineer, scientist, and industrialist which is required to create present and future weapon systems with a minimum of lead time. He gave a brief status report on the ballistic missile and space programs under the direction of the Air Force Ballistic Missile Division, which included the Atlas, Titan, and Minuteman in the ICBM class and the Thor in the IRBM class.

In conclusion, General Schriever said, "Any military leader is first of all professionally versed in military strategy. Beyond this, however, the military leader

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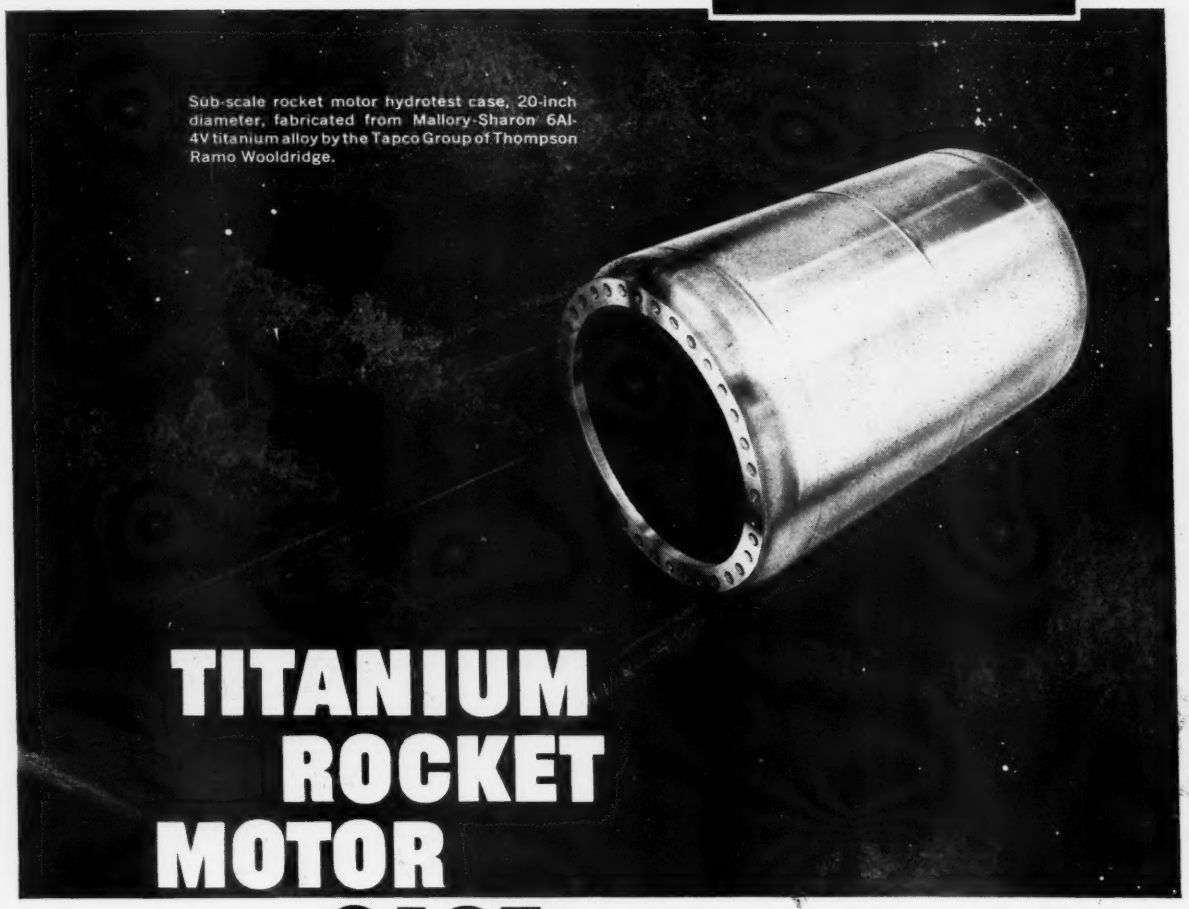
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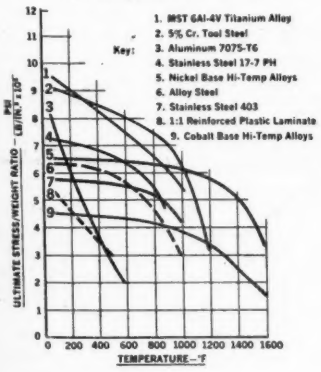
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of the future must have a thorough understanding of the interaction between strategy and technology. This last is, I believe, the most important implication of the space age for the future military leader."

Members and guests were taken on a guided bus tour of the Academy grounds before the meeting, and the evening was concluded with a tour of the laboratories. Instructors provided a brief demonstration of the thermodynamic, electronic, and propulsion laboratory, also the turbojet-engine test cell and supersonic wind tunnel.

WALTER KUEHNEGGER, *Secretary*

San Antonio Section

St. Mary's University Professor Discusses Satellites

The May meeting had as its speaker **Dr. William Hamm,** Professor of Physics, St. Mary's University. Dr. Hamm began by giving a résumé of all the artificial satellites placed into orbit as of that date, including those presumably achieving solar orbit, and also the accomplishments of each. He then progressed to a discussion of the peculiarities of satellite orbits and what causes the various orbital phenomena such as variations in orbital path with regard to both eccentricity and precession.

Numerous fine training aids were used to clarify the discussion—for example, gyroscopes were used to explain the phenomena of precession; "Doppler shift" as affects the transmission from satellites was also considered.

Dr. Hamm also described how St. Mary's University is tracking and plotting the orbital path of Vanguard I.

ROBERT R. PERRY, S.M.Sgt., USAF
Secretary

San Francisco Section

Dr. Wayland C. Griffith of Lockheed Is Speaker

"Scientific Exploration on the Moon" was discussed by **Dr. Wayland C. Griffith,** Associate Director of Spacecraft and Missiles Research, Lockheed Missiles and Space Division, at the May 21 meeting.

Dr. Griffith said that, with manned space travel imminent, consideration is being given to what is really known about the moon in terms of human habitation, and what scientific observations could be made which would extend our knowledge. He noted that the moon would be an ideal station for observing the outer galaxies since the moon has only a fraction of the earth's atmosphere. The moon could be used for a refueling station, either for ships returning to earth or to make more extended journeys. He said that if this potentiality were exploited, an explorer would have a rugged time of it because the lunar terrain contains many craters, faults, and topographical variations (as much as 126,000 ft.). The temperature during the day is about 100°C., but it can drop to -100°C. in an hour. In addition, Dr. Griffith said, it is believed that gases may be escaping from rocks of the lunar landscape. There is also evidence that the landscape may be covered with a layer of dust from perhaps a few millimeters thick to several feet deep. An explorer, however, would experience only one-sixth the attraction of gravity that he would on earth.

Dr. Griffith said that, regarding scientific observations, the moon is well suited to testing Newton's law of gravitation and Einstein's law of relativity. Photography could also be accomplished in the ultraviolet region (500–1,000 Angstroms) where the atoms have their principal natural wavelengths.

NORMAN R. BERGRUN, *Secretary*

Texas Section

Mississippi State's Raspet Speaks on Real BLC

Dr. August Raspet, Head of the Aerophysics Department, Mississippi State College, spoke May 21 at a joint meeting of the IAS and the American Helicopter Society on **"The Real Boundary-Layer Control."**

Dr. Raspet discussed work being conducted at Mississippi State in three fields of boundary-layer control—lift increase, drag decrease, and propulsive efficiency improvement. He showed a film of a light plane modified with BLC by suction. The modification was accomplished simply by punching thousands of small holes in the wing fabric and creating a suction within the wings, from a pump powered by the engine. Stall speed was reduced to 26 m.p.h., and distance to unstick was considerably decreased.

He also discussed increasing the efficiency of compressors, diffusers, jet pumps, and helicopter blades, as well as ducted propellers, all by boundary-layer suction. Dr. Raspet declared emphatically that suction rather than blowing should be used since it required considerably less power for the same job.

VERNON A. LEE, *Secretary*

Washington Section

FAA Administrator Outlines Organization and Activities

Organization of the FAA, and some of its activities, was discussed by **Elwood R. Quesada,** Administrator of the Federal Aviation Agency. Mr. Quesada began by noting the growth of the aeronautical field—and the interests of the IAS—to include much broader fields than was the case 10 years ago. He also stated in his opening remarks that he considered the NACA, now the NASA, to be the finest Government agency because of the quality of the support it has given the field of aviation and aeronautics.

Describing the principal elements of the FAA organization, he stated that the legal counsel has the complex responsibility of rule enforcement in seeing that standards established by the FAA are followed. The newly created office of Civil Air Surgeon has the increasingly important role of public protection by establishing knowledge and criteria for physical fitness and ability to perform public service.

A major office of the FAA is the Bureau of Research and Development, headed by Capt. A. C. Packard, USN. Its principal objective is to develop an Air Traffic Management System which is semiautomatic rather than manual. Mr. Quesada stated that this new Air Traffic Management System would be as complex as any military weapon system devised to date. It must be completely reliable, operate nationwide 24 hours a day, handle airliners from take-off to landing, and embrace all sorts of elements, such as radar, communications, and human decisions. Mr. Quesada said that the FAA would do no in-house research and development work, but would rely on industry. However, the FAA does and will do testing, performance measuring, and evaluation of industry devices so that selection will be on a basis other than intuitive.

Creation of the FAA concentrated the responsibility of rule writing and rule enforcement in one agency. Standards are required, and it is the FAA's responsibility to establish them and maintain them in order to protect the public. Two methods of enforcement open to the FAA are (1) levying a fine which must be paid or settled in court and (2) acting against the certificate of a pilot or a carrier which, if contested, will be referred to a court. He said that every effort is being made to assure that FAA actions are prudent and in the best interests of the public.

Mr. Quesada then brought up the subject of noise—a problem which he feels concerns the FAA deeply. Today and in the future, he said, we will be developing tremendous quantities of energy, a significant portion of which is going into noise. The subject of noise needs more than casual attention, or aviation will bring upon itself severe penalties from the public. The aviation industry is spending a large amount of money on noise abatement, and the Government is beginning to work on this problem. Mr. Quesada is convinced that a public relations problem of considerable magnitude already exists, and the problem cannot be dismissed by pointing out that the same sort of noise problem arose when we developed the Iron Horse and the engineer tooted his whistle when going through town.

In the design of new aircraft, noise can no longer be the factor which always yields to the requirement for speed and altitude. More attention to landing and take-off performance must be given at the price of cruising performance. Those interested in aeronautical science must give increased consideration to noise when laying down the design of new aircraft. In conclusion, Mr. Quesada stated that he did not intend to create the impression that commerce should be retarded, but in order to further commerce the noise problem must be solved.

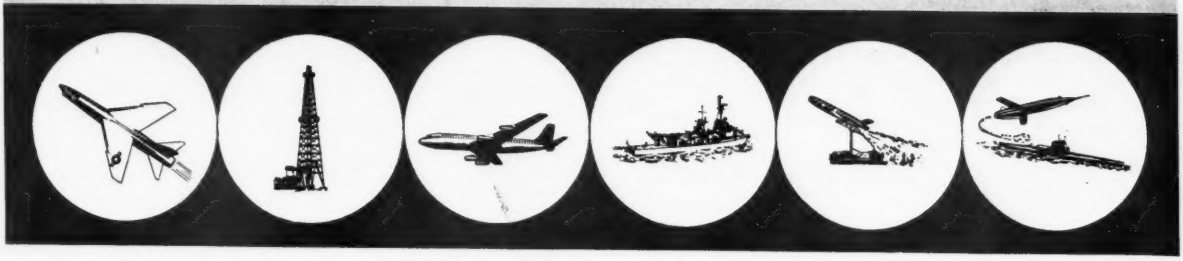
The formal portion of the meeting was followed by a question-and-answer period. Some of the questions and answers are reported here:

Q: What is being done to gain relief from the crowded situation in the jet route structure above 29,000 ft. which

(*Continued on page 114*)

SARGENT

SERVO-SYSTEMS OF FORCE CONTROL



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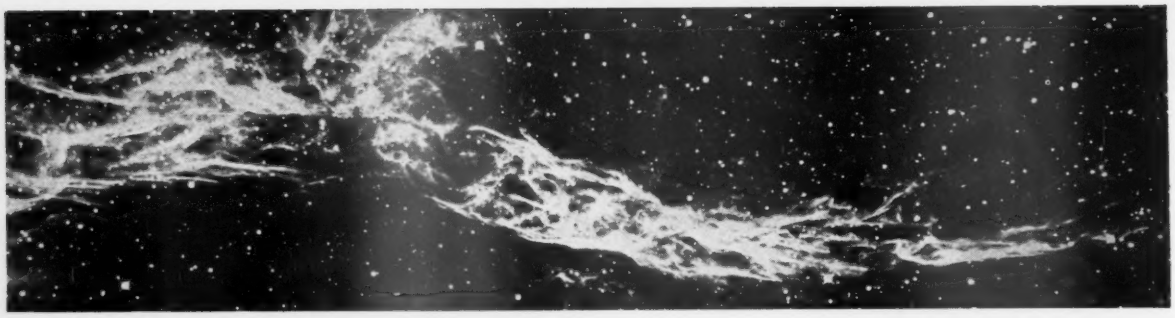

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DATELINE World

PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

Two Papers on Hypersonics Found of Unusual Interest

◆ A U.S. aerodynamicist, who has been examining U.S.S.R. contributions in hypersonics, has recently reviewed two Soviet papers which he considers of more than passing interest.

The first paper is titled "The Equations of a Three-Dimensional Boundary Layer in a Compressible Gas for an Arbitrary Surface." Written by V. V. Struminskiy, it appeared in *Doklady Akademii Nauk SSSR*, Vol. 114, No. 2, pp. 271–274, 1957.

V. V. Struminskiy is one of the leading theoretical aerodynamicists in the U.S.S.R. He was one of the 15 scientific experts recently elected to the Presidium of the National Committee on Theoretical and Applied Mechanics.

The second paper reviewed is by E. P. Vavlin of Moscow State University, titled "On the Temperature of a Flat Plate Across Which Flows a Reacting Gas Mixture." It appeared in *Zhurnal Tekhnicheskoy Fiziki*, Vol. 27, No. 7, pp. 1390–1396, 1957.

Caprolactam Being Made by Photosynthesis Process

◆ A new experimental facility for producing caprolactam by means of photosynthesis has been set up in Soviet Armenia. The basic materials used are cyclohexane and nitrosylchloride which, when subjected to light, are converted into raw capron. In contrast to the presently used multistage chemical synthesis, the new technological process is simple and inexpensive, the Soviets say.

Solution to Flutter Problem Found in Windmill Experiment

◆ *Soviet Aviation* magazine for December 14, 1958, reports that an Engineer-Candidate of Technical Sciences, as an experiment in his investigations of flutter, connected the propeller blades of a fast windmill to the hub by means of a flexible component and produced self-vibration of the blades similar to flutter in aircraft. His experiment proves, the item states, that windmills having vibrating propeller blades have a high utilization factor of wind energy. The Soviet investigator contends that by applying the principle of flapping wing flight to windmills he has found the way to control, and even make advantageous use of, the dangerous flutter phenomena that have been the cause of many air disasters. A commission of the Academy of Sciences, interested in the utilization of wind forces, has made a recommendation that the experiments be continued with self-vibrating propeller blades in order to determine their aerodynamic characteristics.

99.99999 Per Cent Pure Aluminum to Be Made in U.S.S.R. Plant

◆ Soviet metallurgist V. Semenov has announced that a sample of aluminum 99.99999 per cent pure has been produced by sublimation in a special vacuum installation at the Kalinin Institute of Nonferrous Metals. Professor A. I. Belyayev, who occupies the Chair of Light Metals at the Institute, developed the method, which thus far has produced only small quantities under laboratory conditions. The Soviets refer to the superior product as "seven-nines" aluminum, and claim that it is much softer and more ductile than commercial aluminum. It is described as having good antimagnetic properties and greatly improved residual resistance at −271°C. Also, heat and electrical conductivity, light-reflecting properties, and corrosion resistance are said to be high. Semenov reports that a semi-industrial plant has already been designed for production of "seven-nines" aluminum.

New Type of Propeller Seen on IL-18 Turboprop

◆ A photograph of an Il-18 four-turboprop transport in the November, 1958, issue of the Soviet publication *Civil Aviation* is of interest in its revelation that the Soviets are using rectangular planform propeller blades of metal construction. It had been believed that the Soviets were using only wood for rectangular blades.

Using the front nacelle ring as a dimensional reference, the diameter of this propeller has been established as 14.6 ft. and the maximum blade chord as 1.4 ft. These dimensions are unchanged from those of the elliptical metal blade used on the Il-18 aircraft. The rectangular planform, however, increases blade activity factor (measure of propeller's ability to absorb power) from 102 to 150. The propeller illustrated should be suitable for installations in the 4,000–6,000 s.hp. range. If these blades are in series production, they represent a significant advance in Soviet propeller technology.

Radioelectronics Future Seen in Production Processes Automation

◆ In March of this year, in connection with the centennial observance of the birth of Alexander Popov, a prominent Soviet scientist gave his views on the future of radioelectronics in the U.S.S.R. and predicted that the main line of development in radioelectronics will be in the automation of production processes.

The commentator, Vladimir Siforov, is a corresponding member of the U.S.S.R. Academy of Sciences, and Chairman of the Scientific and Technological Society on Radio Engineering and Electrical Communications. In his remarks commemorative to the Marconi of the U.S.S.R., Siforov made particular mention of electronic computers, which, he said, "will carry out large numbers of mathematical operations and intricate logical actions," in their important role in the automation of production.

He mentioned medicine, biology, geology, and astronomy as other fields where radioelectronics will become increasingly important. He scoffed at those who hold that the saturation point has been reached in the use of radio in its original sphere, predicting that innovations in radio communication will come from a closer study of the shorter radio waves.

"While the transition from short waves to ultra-short waves gave us the benefit of television, radar, etc.," Siforov stated, "the continual shortening of the wavelengths will, it seems, lead to radio vision—i.e., the actual seeing of distant objects when there is no optical visibility."

He spoke of so-called quantum radioelectronics as a promising new trend in radio engineering, and cited molecular generators of electrical oscillations as an example of progress already made in this sphere. He pointed out that time can be measured by these radio generators with a margin of error of only 1 sec. in 3,000 years.

Referring to the Mechta launching, Seminov pointed out that radioelectronics were employed in the launching, in the calculation of the rocket's trajectory, in the transmission to the earth of diverse and valuable data on cosmic space, and in the analyzing of these data.

REVISED OPERATIONAL PLAN FOR THE IAS
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APPROVED BY COUNCIL - 27 JANUARY 1959
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EDITORIAL

New Constitution

Over the past several years it has become increasingly evident that the changing times require some re-examination of the basic rules for operation of the IAS. No significant changes have been made in the Constitution since the Institute was founded some 27 years ago. In its early years the IAS served a small and compact industry. It was then relatively easy for a few people to keep abreast (or ahead) of technical and scientific trends and to lay plans and programs accordingly. Under present conditions, however, this is no longer possible. Our industry has become large and diversified. The interests of our members extend into areas undreamed of a quarter of a century ago. Management now requires continuous advice from many sources to keep up with the professional requirements of the membership in the rapidly expanding areas of Aero/-Space Technology.

Over a year ago, E. C. Wells, then IAS President, appointed a Long Range Planning Committee to study the problems and to recommend to the Council procedures adequate to meet current situations more effectively. At a meeting of the Council held in Princeton, New Jersey, on October 28, 1958, the Director presented (as a part of this program) a staff study containing a Proposed Operational Plan which made provisions for (a) broader Council representation, (b) Regional-type operation, and (c) the establishment of certain standing Policy Committees and Aero/Space Technology Panels. The details are shown in the accompanying chart.

The plan was distributed to all Sections of the IAS for comment, and discussed with many Section Officers and many interested members. The Proposal, together with suggestions that had been received from the Sections and from other sources, was carefully studied by the Long Range Planning Committee and by the full Council in January, 1959. At that meeting general approval was given to the Proposal. The Staff was directed to prepare the necessary changes in the IAS Constitution and By-Laws to make them consistent with the proposed program.

At the Spring Council Meeting held in Washington on April 23 a careful study of the modified Constitution and By-Laws was made. All suggestions that had been received from all sources were evaluated, and a new draft prepared, incorporating all ideas that were not inconsistent or irrelevant. This draft was then reviewed by our Legal Counsel for consistency with our Charter and with the Laws of the State of New York under which we are incorporated. At the meeting of the Council held in Los Angeles on June 17, the revised draft was discussed in detail, and the final document approved.

Generally speaking, the purpose of the modifications in Constitution and By-Laws is to improve the channels of communication between members and management and to secure the best possible (and continuing) advice with respect to technical and scientific programs to satisfy the professional needs of the members. The latter is the primary function of the Aero/Space Technology Panels. (Note: The Panels shown on the chart are not necessarily final, but may be modified by the Council to meet changing future requirements.) Changes have been made in the composition of the Council and the terms of its members. The several regions of the country now have the opportunity to nominate their own representatives on the Council, and the Regional Vice Presidents and the Council Members for the regions will serve longer terms for greater continuity. Although there is no legal restriction on the number of geographical regions that may be established by the Council, three have been approved as a beginning. Further subdivision, if deemed desirable in the future, is within the power of the Council. We believe that careful reading of the new Constitution and By-Laws with cross-reference to the accompanying chart will give a clear understanding of the new arrangement.

In accordance with Article 11 of the present Constitution, a copy of the proposed Constitution (together with the new By-Laws), showing the original and proposed changes, has been mailed to voting members of the IAS. Accompanying the new Constitution is a ballot on which they may express approval or disapproval. If approved, it is expected that these changes will go into effect at the end of our fiscal year (September 30, 1959) so that nominations for Officers and Members of the Council for the calendar year 1960 can be made in accordance with the new plan. It is urged that every member take advantage of this opportunity and return his ballot as soon as possible to the IAS Secretary at the New York Headquarters.

S.P.J.

XUM

This paper serves to "focus attention upon those human qualities which may be utilized to augment system reliability—for the reliability problem in space is at least as onerous as providing for human physiological necessities."

A Positive Approach to Man's Role in Space

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A PRELIMINARY SYSTEM design proceeds by determining (1) prime system goals, subgoals, and their feasibility; (2) alternate mechanization schemes for achieving subgoals; and (3) a selection between alternate mechanization schemes so that a given prime system goal will be approached in some optimal sense.

In carrying out the foregoing procedure, the systems designer must have both general knowledge of prime problem areas, as well as detailed knowledge of component characteristics as they affect system success or expected system performance. System success is the product of system performance and the probability of achieving this level of performance. In space flight this probability, or overall system reliability, is critical because of long mission durations, weight limitations, and remote locations, so the designer must examine alternative components with system reliability foremost in mind. Man is a possible system component with extremely versatile capabilities, some of which bear directly on the problem of reliability improvement. To some extent his abilities in reliability improvement can be the key to a framework for evaluating man's role in space systems. Subsequent structuring of this framework here can be of value in determining whether much space exploration should be a vicarious sensation or whether the presence of man as an active participant is desirable. In fact, the framework constructed may reveal, if carried to a logical conclusion, that some complex space missions are manifestly impossible if unmanned.

Popular Notions on Man's Space Role

At present there are two related reasons which summarize engineering opposition to manned space flight:

(1) The mission may be such that manned flight is not meaningful.

(2) The environmental and flight path requirements imposed by manned flight involve complications of such magnitude as to compromise the mission.

Some of the factors subsumed in the second statement will be more thoroughly outlined in later paragraphs as the details of the theme evolve. On the other hand, the case for manned space penetrations has often been stated in terms of such nonquantifiable concepts as:

(1) Manned space flight may serve to improve the national position in world politics.

(2) Manned space flights may confer some military advantages on us.

(3) Man's destiny demands his entry into outer space "because it's there."

In more functional terms, man has been viewed as an ideal component of sorts, capable of serving as an organizing, computing, decision making, controlling, actuating, and information-recording system. While such capabilities, indeed, offer enticing and positive contributions, their potential value is often shrugged off as inconsequential in view of the excessive price

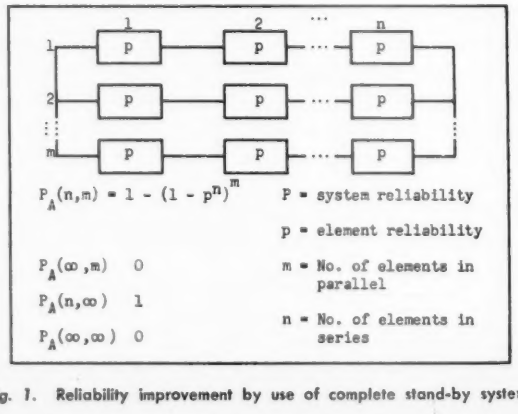

Fig. 1. Reliability improvement by use of complete stand-by systems.

Mr. McRuer received his B.S. and M.S. degrees from the California Institute of Technology. He is President of Systems Technology, Inc., which is engaged in research, development, and consultation in the technical fields of automatic and manual control systems, aeronautics and astronautics, component and system reliability, and human dynamics. Prior to the formation of Systems Technology, Inc., Mr. McRuer was successively employed by Northrop Aircraft, Inc., and Control Specialists, Inc. For the past 12 years his major efforts have been devoted to research, development, and design of automatic flight control, navigation, fire control, and guidance equipment. In recent years he has also worked in the field of man-machine systems, from both the handling quality viewpoint and in the measurement, analysis, prediction, and simulation of the dynamic response of human pilots.

Mr. Ashkenas received his B.S. and M.S. degrees from California Institute of Technology. He is presently Vice-President of Systems Technology, Inc. Prior to the formation of Systems Technology, Inc., Mr. Ashkenas was successively employed by North American Aviation, Inc., Northrop Aircraft, Inc., and Control Specialists, Inc. For the past 20 years Mr. Ashkenas has worked in the aerodynamic design areas of stability and control, performance, and aeroelasticity. During the past 5 years he has added to this broad aerodynamic background extensive studies of automatic flight control systems and the dynamics of human response.

Mr. Krendel received his B.S. in physics from Brooklyn College in 1945, Sc.M. in physics from M.I.T. in 1947, and M.A. in social relations from Harvard in 1949. He is Head of the Engineering Psychology Branch of the Franklin Institute Laboratories and has served as a human factors consultant to government and industry. He is the author of approximately 20 technical reports and has presented numerous papers before technical society meetings and university, government, and industrial symposia. Mr. Krendel is a member of the Operations Research Society of America, the American Psychological Association, and the Scientific Research Society of America and is a senior member of the Institute of Radio Engineers

paid to contend with physiological requirements. Rather than concede before such formidable obstacles, we shall focus attention upon those human qualities which may be utilized to augment system reliability—for the reliability problem in space appears to be at least as onerous as providing for human physiological necessities.

The Reliability Situation

A thorough study of the space vehicle reliability problem considering all component factors has yet to be made. However, some rough estimates of probabilities of success for space vehicles incorporating quite simple equipment indicate that reliability will probably be an extremely stringent factor in advanced space missions. Reference 1, for example, considering only rudimentary control equipment (attitude control using astrotrackers, computer, and reaction wheels) and using failure rate data based on current state of the art components, estimates a probability of success of the order of 0.20 for an 11-day circumlunar mission. For a 95-day one-way rocket to the vicinity of Mars, with even less equipment than the lunar shot, the success probability is estimated to be of the order of 0.05! Even with considerable improvement, it is apparent that more advanced systems, with all equipment considered in the reliability estimate, may well be completely untenable from a reliability standpoint alone. Recognition of the problem and emphasis on the development of components will ultimately be reflected in the equipment for future vehicles. Even then, and more so in the interim periods, it can be appreciated that operation of complex equipments in a space vehicle with long operating times presents a Herculean problem.

Reliability Improvement

The bleak reliability picture can be improved by several means—component development, intermittent operation, and planned use of redundancy.

The improvement of components by improvement of manufacturing techniques, design with reliability of operation as a major consideration, and outright invention of more reliable devices results in relatively gradual and modest improvements in overall system reliability. The problem is such, however, that orders of magnitude in improvement are needed, and these require "breakthroughs" in various aspects of the entire technology. Such possible radical advances cannot be made a part of present systems planning, although future design plans can be modified as they occur or become imminent.

The intermittent operation of equipment on long trips offers possibilities for increasing mission reliability both from the viewpoint of component calendar life, as well as in decreasing demands on the vehicle's stored and generated energy. If constant-hazard operation is assumed, then obviously the failures occurring over the total elapsed time are reduced by intermittent operation. Such an idealized picture does not take into account the effects of starting and stopping conditions which may violate the assumption of constant-hazard. Nevertheless, if the total on-time can be reduced by an appreciable factor, intermittent operation will undoubtedly improve the elapsed-time life of the system. Such intermittent operation implies, of course, an ultrareliable, continuously operating, decision-making system to determine when shutdown and start-up shall occur.

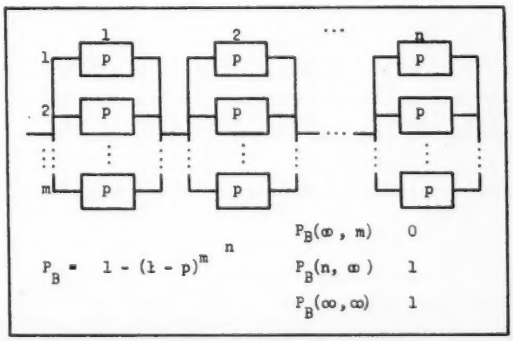

Fig. 2. Reliability improvement by use of parallel modular technique.

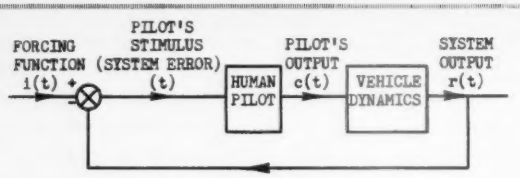

Fig. 3. Compensatory tracking situation.

The most effective method of improving the reliability picture while still employing "state-of-the-art" equipment is the use of redundancy—i.e., paralleled equipment. Fig. 1 (from reference 7) indicates the kind of reliability advantage to be gained from the use of complete stand-by methods. Here the overall reliability P_A is seen to approach unity for a finite number of series elements n, as the number of parallel elements m is allowed to go to infinity. But it must also be noted that, as n approaches infinity, the reliability P_A goes to zero.

A more advantageous system mechanization is indicated in Fig. 2 (also taken from reference 7). Here the system reliability P_B goes to unity as both m and n approach infinity.

It has been tacitly assumed in both cases that the detection of a faulty element and the switch-in of a replacement can be accomplished with negligibly small uncertainty in a very short time. Also, the requirement exists that m, the number of parallel elements, must approach infinity for the system reliability to approach unity. There are three mechanisms which can tend to satisfy physically these three mathematical requirements—all of which currently require the presence of a human for systems of moderate or great complexity: failure detection and isolation, component replacement, and equipment repair.

Full utilization of component replacement and repair possibilities implies the use of a minimum variety of standardized, interchangeable modules throughout the various systems in the vehicle, with each module in turn being made up of interchangeable parts. Then, with a small stock of spare modules and parts, an actual physical system with only one or two redundant channels can approach an effective system with much more redundancy, with the man serving as judge over mechanical inconsistencies. Thus a prime human role in space will be that of failure detection, replacement, and repair. The analogy with long time detached operations with naval craft is obvious.

Other Human Contributions to System Reliability

Besides the cardinal virtues of a spatial handyman, other capabilities can be oriented toward and related to system reliability improvement. These are described in the following:

(*A*) *Man's ability to control and to actuate* is a major means for increasing reliability by the deletion or simplification of navigation and control equipment. Man is still the best adaptive-optimalizing servo for systems with rapidly and widely varying controlled-element dynamics. In "idiot" tasks it is trivial to design a servo which can excel him, but no servo has as yet outperformed man when he is used where his inherited and trained abilities are properly applied.

Man's potential as an adaptive-optimalizing controller is of particular interest for the control of space vehicles since many advanced missions will involve large changes in vehicle dynamics in quite short time intervals. To cope with changes in controlled element —i.e., vehicle—dynamics, automatic control engineers are now evolving some relatively sophisticated devices known as adaptive servos. These operate by sensing changing control requirements and then modifying their parameters appropriately. A difficult problem for the most advanced or manlike devices of this sort is that sensing and criterion evaluation take time—tantamount to reaction time delay in a human controller. Thus the rapidity of an adaptive servo's criteria evaluation process can become critical in situations with rapidly varying controlled-element dynamics. The adaptive-optimalizing human controller has been performing such criteria evaluation and adjustment functions rapidly and effectively for controlled-element characteristics ranging from Pogo sticks to the X-15 since man evolved to his present state.

The Human as an Adaptive Servo

The adaptability of a human controller has, of course, long been cited as an obvious capability and then dismissed for many closed-loop control applications because of the attendant human time lags. Such short shrift has often been justifiable in the past because the control situation has been relatively stationary and man as a competing controller has not always been allowed to function in the most effective fashion. In particular, man's ability to suppress the overall effects of reaction time delay under certain conditions has often been ignored. Since an understanding of human control capabilities is essential to his proper evaluation as a competitive control system element, it is appropriate at this stage to digress slightly from our main theme for a short review of human controller adaptability.

Human adaptation as a control device can be categorized into two general processes:

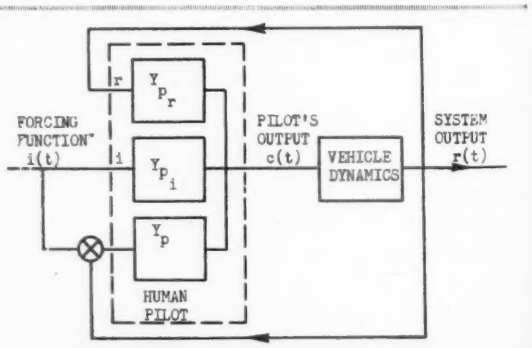

Fig. 4. Effective control system form in second human adaptation process.

(1) Adaptation and optimalization in a given control situation.

(2) Further organization of the control process, with subsequent "effective" modification of the control situation.

These two processes can be simply illustrated in terms of servosystem block diagrams. The first process is shown in Fig. 3 for a compensatory tracking situation with a random-appearing forcing function.

It has been shown,[4, 5] for both ground simulator and flight situations, that a crude approximation to the human's describing function is

$$Y_p = [K_p e^{-\tau s}(T_L s + 1)]/[(T_I s + 1)(T_N s + 1)] \quad (1)$$

where

s = Laplace transform variable
τ = reaction time delay ($0.12 < \tau < 0.2$ sec.).
T_N = approximation to neuromuscular lags
$(T_L s + 1)/(T_I s + 1)$ = pilot's equalization characteristic
K_p = pilot gain

In the above form, the pilot adapts his gain and equalizing characteristics, the $K_p(T_L s + 1)/(T_I s + 1)$* term, to obtain what he considers to be an optimum (controller-controlled element) system response to the forcing function. In other words, the equalization characteristic is adjusted in form to that of a lag-lead, lead-lag, or pure gain, as appropriate, and the equalization parameters and gain are then selected by some internally generated criteria. Empirically it has been determined that the values of these parameters are similar to those a servoengineer would select if he were given a device to control together with a controller "black box," having elements within it making up the describing function given by Eq. (1), with knobs on the outside for adjustment of T_L, T_I, and K_p. While the internal criteria are not known, it has been observed that parameter selection is ordinarily consistent with a phase margin between 60 and 90 deg. Readjustment when different controlled-element characteristics are inserted into the problem can be quite rapid (0.5 to 1.0 sec.).

The inevitable penalty paid for all this adaptability is indicated by the reaction time delay term in Eq. (1). In many control tasks, the corresponding lags become a crucial and critical factor. Indeed, the reaction time delay has played a central role in the elimination of the human as a possible controller for many applications.

The phase lag due to reaction time delay is often mitigated by the second process of human adaptation.[6] As a result of training and past experience, the operator can often detect and take advantage of part of the internal coherence and predictability of his input signal (the error in Fig. 3). When this can be done, the effective nature of the actual physical control situation changes from the compensatory case shown in Fig. 3 to an effective combination open-cycle, closed-cycle control system as shown in Fig. 4. Here the operator still exerts continuous closed-loop control of the vehicle, but his ability to make short-term predictions about the forcing function and the vehicle output allows him to "insert" the additional blocks Y_{p_i} and Y_{p_r}. In practice, these blocks compensate for the predominant reaction time delay lags which first led to control difficulties when the system was effectively, as well as physically, compensatory.

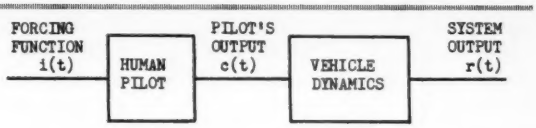

Fig. 5. Alternative effective control system in second human adaptation process.

Finally, in situations where the operator is able to detect and take advantage of all the internal coherence and predictability of his input signal, the effective situation becomes precognitive (Fig. 5). In this instance, the central nervous system resembles a programer emitting an entire repertory of command signals to the neuromuscular system based upon a complete "knowledge" of the forcing function and the operator's lags. This response is essentially open loop, and the effective system is analogous to a programed controller.

The second human adaptive process described above may be thought of as the result of a structuring internal to the operator. The process itself is a progression from a compensatory display organization (the actual physical system), through a pursuit-type organization, and finally ending up as an open-loop response. Thus, although it might be extremely difficult, an operator working with a compensatory display can demonstrate, by dint of much training, "effective" open-loop control in some tasks with a limited repertory of deterministic input stimuli. An inanimate adaptive servo capable of a similar progression, and which also has the same range of adaptability as that shown in the first phase, is as yet to be achieved.

The Human as a Power Output Device

The above remarks on manual control capabilities are centered upon sensing and equalizing features in closed-loop control which generally involve the pilot's *dynamic performance* characteristics. Just as in conventional servosystems, man should also be characterized in *power output* terms.[3] For present-day airframes, the possibility of utilizing human muscle-power for the large variety of actuation functions that are performed has gradually dwindled until man's only characteristics of real importance are those defining his dynamic performance. It is anticipated that such will not be the case in space missions, where man's muscle-power may represent a significant contribution to the total energy available. Thus, the use of direct manual control on the orientation of reaction-jets, the braking or acceleration of inertia wheels, the generation of electrical power, etc., are examples of the uses to which man can be put

* In certain restrictive instances, generation of a second-order lead has also been observed.

in a power output sense. These aspects of man's capabilities may be just as important as his dynamic performance in a closed loop if full advantage is to be taken of his presence to improve reliability and decrease total energy requirements.

The foregoing remarks are intended to point up human capabilities as an adaptive servo and power output device, and not to decide any potential competitions between man and machine. Assuming adequate performance by both possibilities in given tasks, then the use of man as a unique or parallel controller should be decided on overall reliability considerations in terms of specific proposed mechanisms. Thus whether reentry flight should be manual, or automatic with an override, cannot be decided without a detailed analysis of the interacting factors involved.

(*B*) *The ability to organize data and to make decisions* enables reliability to be increased in several ways. Three of these—failure detection, replacement, and repair—have been previously discussed. In addition, intermittent operation of much of the equipment can be effected easily if a human makes the on-off decisions. In re-engaging operations, the human can satisfy gross guidance and control requirements, and appropriate command can then be given to equipment suitable for finer control. The human also fits well into intermittency concepts since he is capable of sustained low-energy operation even while fully engaged in monitoring functions.

Decision-making ability viewed in a general sense enables a manned mission to operate in unforeseen circumstances. Such modes of operation are clearly of importance in military and in exploratory missions where preprogramed decisions are not feasible. Since mission goals may be subject to change during the course of a flight, the rank ordering of the tasks which must be performed sequentially to accomplish the mission's needs may change as well. Under these circumstances, a man can reassign priorities to tasks with a sophistication beyond the capability of a machine. In a crisis the proper choice of the first things to be done is likely to be as important as doing them properly.

(*C*) *Observation and memory functions* are relevant to such matters as navigation and rendezvous procedures, as well as to general exploratory capability. Observation interacts with control functioning in this event since, for example, the observation of an appropriate landing area on a planet does not influence mission performance unless the man can control the vehicle so that it lands in the desired location. Memory, as a storage of a repertory of behavioral responses, resulting from training as well as stored observations, is relevant to both mission performance and intelligent observation. The ability to filter or organize observations in terms of an underlying structure is a necessity in exploratory activity. Without this ability, one would record data either in its entirety or according to an arbitrary scheme. In the first case a large amount of data would have to be gathered, stored, and/or transmitted, and in the second case valuable data could be missed. In either case, a weight-energy or mission performance penalty results, with the attendant reliability decrease.

Negative Aspects of Manned Space Flight

Most of the negative consequences of man's presence in space follow from the energy and weight requirements of equipment needed to maintain human life at an effective level. This energy represents the medical penalty we pay in order to enjoy man's behavioral abilities. In a formal sense, these medical requirements are the same as the various environmental restrictions, tolerable *g* forces, temperature, humidity, etc., which are placed on equipment if it is to operate at a specified level of reliability. These human component environmental requirements have been extensively covered in the literature so only a short summary is presented here.*

Respiration

(1) The O_2-CO_2 cycle which is characteristic of life on the surface of the earth must be maintained by regulating the partial pressures of the gases in the synthetic atmosphere.

(2) The inhaled gases must be kept free of toxic compounds. This requirement can be severe in that certain toxic compounds have a cumulative effect; consequently, even minute amounts may be dangerous.

Food

(1) A stock of food and liquids will have to be carried on board.

(2) Plans will be needed for eliminating metabolic wastes.

These two related problems can be alleviated, to a certain extent, by altering the metabolic efficiency of the man by drugs and appropriate diets and by liquid extraction and purification procedures applied to waste products.

Environment

(1) Weightlessness and its behavioral results constitute an area of poorly understood problems.

(2) Temperature controls must be exercised.

(3) Radiation hazards, since they are cumulative, require a shielding which is a function of both trip length and the radiation intensity level.

(4) There must be constraints on the flight path so as to keep the *g* forces within the acceptable limits which manned flight requires.

(5) The cabin pressure must be maintained within livable limits.

(6) There is a miscellany of environmental factors such as seating, sleeping problems, movement room, safety procedures, and so forth which also involve weight penalties of considerable magnitude. Such

* For reasons of simplicity, this summary is predicted upon a relatively "open-loop" ecology appropriate for moderate length space missions. For missions of greater length, the problem of providing regenerative ecological "equipment" is yet to be solved—e.g., reference 8.

problems as light-dark cycle changes do not involve major weight problems.

Social Factors

(1) Individual isolation effects still present the possibility of a neurotic episode after leaving Mother Earth.

(2) Social effects must be considered for group isolation situations.

It is of interest to note that certain of the requirements imposed on the space vehicle for manned flight are not functions of the number of men abroad. Thus flight path constraints, radiation shielding thickness, nontoxic material requirements, and so forth do not change with the number of men aboard.

Control and Display Requirements

(1) In order for man to be an effective controller, it may be necessary that the transfer function of the spacecraft, as it is presented to him, be restricted within certain limits. This can involve additional control system elaboration.

(2) For man to function, various displays, controls, voice links to ground, and so forth will be needed. All this increases the overall system complexity.

Manned Versus Unmanned Space Flight

In any system problem, the evaluation of competing mechanizations requires a series of trade-off studies. Decisions relating to manned versus unmanned space flight should, from an engineering standpoint at least, be approached in the same fashion. To make such studies meaningful, the foregoing recitation of man's good and bad points needs more substance in terms of quantitative experimental results. The limited data currently available require considerable augmentation before the line between manned and unmanned space missions can be convincingly drawn.

An experimental research program is needed to provide better estimates of "human component" characteristics. Some parts of this program can be carried out on the ground. Other portions must be performed in actual space vehicle missions. By formulating a program of this nature, in advance of our successive penetrations into space, each such step can be made to serve as a logical support for its successor, and many of the experiments can be performed in conjunction with those initiated for other purposes.

The context in which these "human component" investigations should be carried out is different from that characterizing most human engineering studies. Both human operator selection tests and human engineering requirements on equipment design are logically related and have a common goal. This is to achieve a pairing of men and machines whose performance in concert is optimal in some sense. Selection tests approach this goal by extracting proper operators for a specified machine from a population of potential operators. Human engineering requirements on equipment are aimed at simplifying the task demands so that the population of potential operators is increased to such an extent that rudimentary selection rules can be used. Except for extreme cases, the decision to emphasize human engineering or selection can be based on the fraction of the total potential population of users which the required operators represent. Thus, military action by masses of men who must be trained and assigned rapidly makes conventional human engineering considerations of primary importance and sophisticated selection and training techniques secondary. If, on the other hand, a small number of men are required for particularly exacting tasks, then selection and training techniques assume primary importance. Clearly, space travel falls in the second category. Selection tests and training procedures may be expected to derive in part from the experimental program outlined below. Medical criteria and personality criteria will, of course, complement behavioral criteria for space pilots. The subjects for the experimental program should, in the main, be preselected and trained to an extent rarely achieved or required in human engineering studies. This does not rule out the usefulness of performing limited experiments on less highly selected subjects for qualitative or preliminary experimental design purposes. The main goal of the program remains, however, as the description of the functioning of unusual rather than common men.

The following examples of problems to be explored, from the *behavioral* rather than medico-environmental aspects of human functioning, serve to structure this experimental program:

Control and Actuation

These experiments will involve measurements of pilot input-output describing functions and other controller characteristics in the following situations:

Conventional Control Tasks With Space Vehicle Dynamics

(1) Controlled-element transfer functions for free space attitude control, using inertia wheel, external jets, and internal mass distribution controls. Consideration should be given to unmodified vehicle dynamics, various forms of augmentation, and display aids.

(a) In laboratory simulations, under both ordinary conditions and those with induced pilot nausea and disorientation.

(b) In MIS types of vehicle.

(2) Time-varying, controlled-element simulation (atmospheric exit and entry).

(3) Implications for training so that the pursuit and possibly precognitive levels of human skill may be approached as closely as the state of the art permits.

Adaptive Servo-Human Controller Comparisons

To determine parameter adjustment capabilities and times for man and machines over a range of controlled element dynamics anticipated for space vehicles.

Actuation, Muscle Power, and Energy Conversion Abilities

To extend and correlate much presently existing data into a form specifically applicable to space vehicle use and problems.

Organization and Decision

Replacement and Repair

(1) Module replacement and repair studies to determine optimum modular units.

(2) Randomized failure detection studies.

Determination of a reliability description for man compatible with complex electromechanical equipment reliability descriptions—e.g., reference 2

Determination of displays, outputs, and training needed to optimalize man's choices between disagreeing systems, and man's capacity to repair malfunctions

Observation and Memory

Specifications of Training for Men

(1) In terms of specific observations for exploratory purposes made from TV types of display.

(2) In terms of background experience—i.e., expertness in pertinent areas of science and engineering.

"Fire Drill" Training

The results of such experimental programs as those noted above will enable the systems designer to maintain up-to-date trade-off curves for manned versus unmanned space flight. These trade-offs will compare the reliability and mission performance advantages of manned flight with the weight-energy penalties imposed. They can be related to the mission requirements and the range of flight duration in order to determine whether the *system* can operate at a desired level of reliability. *In this way, the issue of manned versus unmanned space flight can be decided on the basis of rational probabilities for accomplishing a space mission of a given type, duration, and energy requirement.*

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FF-19	Combustion—An Aeronautical Science—H. W. Emmons, 1958 Minta Martin Lecture.	0.75	1.25
FF-18	On the Main Spray Generated by Planing Surfaces—Daniel Savitsky and John P. Breslin.	0.75	1.25
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FF-16	Inertial Guidance—W. Wrigley, R. B. Woodbury, and J. Hovorka.	0.75	1.25
FF-14	Engineering Management Philosophies (a Symposium).	0.50	1.00
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FF-9	A Hydrodynamic Study of the Chines-Dry Planing Body—Experimental Towing Tank, Stevens Inst. of Tech.	1.20	1.60
FF-7	Natural Flight and Related Aeronautics—James L. G. Fitz Patrick.	2.65	3.50
FF-4	Finite Deflections of Curved Sandwich Plates and Sandwich Cylinders—F. K. Teichmann and Chi-Teh Wang.	0.50	0.85

No.		Member	Nonmem.
FF-3	The Penetration of a Fluid Surface by a Wedge—Experimental Towing Tank, Stevens Inst. of Tech.	$1.20	$1.60
286	Linearized Treatment of Supersonic Flow Through Axi-Symmetric Ducts with Prescribed Wall Contours—Charles E. Mack, Jr., and Ignace I. Kolodner.	0.75	1.25
229	Wave Profile of a Vee-Planing Surface, Including Test Data on a 30° Dead-Rise Surface—Experimental Towing Tank, Stevens Inst. of Tech.	1.20	1.60
170	Wave Contours in the Wake of a 10° Deadrise Planing Surface—Exp. Towing Tank, Stevens Inst. of Tech.	1.20	1.60
169	The Discontinuous Fluid Flow Past an Immersed Wedge—Experimental Towing Tank, Stevens Inst. of Tech.	0.75	1.00
168	Wave Contours in the Wake of a 20° Deadrise Planing Surface—Exp. Towing Tank, Stevens Inst. Tech.	1.20	1.60
167	On the Pressure Distribution for a Wedge Penetrating a Fluid Surface —Experimental Towing Tank, Stevens Inst. of Tech.	0.75	1.00
126	External Sound Levels of Aircraft—R. L. Field, T. M. Edwards, Pell Kangas, and G. L. Pigman.	0.75	1.00
106	Measurement of Ambient Air Temperature in Flight—W. Lavern Howland.	0.35	0.50
104	Tensor Analysis of Aircraft Structural Vibration—Charles E. Meck, Jr.	1.85	2.50
102	Electrical Resistance Strain Gages Applied to Wind-Tunnel Balances—Elmer C. Lundquist.	0.60	0.80
101	Introduction to Shock Wave Theory—J. G. Coffin.	2.65	3.50
100	Blade Pitching Moments of a Two-Bladed Rotor—R. W. Allen.	0.75	1.00

Elements involved in the materials-structures problem area are examined for compression and tension structures, and the nature of the interplay between design parameters and the mechanical properties of materials is reviewed. Thermal protection systems—which constitute a notable example of this interplay—are also discussed.

Structural Interplay:
Design and Materials

George Gerard, AFIAS

New York University

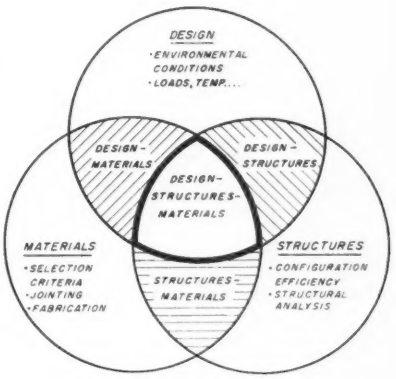

Fig. 1. Nature of the interplay.

THIS PRESENTATION is not an apology for the so-called limitations of materials. Neither is it an attempt to delineate for the materials fraternity the fairly well-known extreme elevated temperature conditions commonly associated with the design of hypersonic and re-entry vehicles. Rather, it does constitute an exploration of some of the less tangible aspects of the design-structures-materials complex to assess the significance of the demands of design. Since the demands of design are based on certain intangibles that are not readily accessible to those concerned with materials, the purpose here is to go behind the scenes in a rather selective fashion to explore the interplay among design, structures, and materials.

The advent of jet propulsion introduced an age which has placed great demands upon materials, the tangible embodiment of design. With nuclear propulsion and thermal flight of air vehicles and their associated severe environmental temperature conditions, the demands upon materials have increased sharply in the past decade. Furthermore, the demands are in an area which require significant quantities of time and money to translate the promising results of research into materials of construction in suitable forms. All this in an area where the usual free enterprise incentives are notably lacking and the potential market is ill-defined.

The emphasis in this presentation is upon the demands of design rather than upon the limitations of materials since the latter viewpoint denotes a psychologically unrealistic attitude toward the world we live in. Dreaming about removing limitations of materials provides powerful incentives for research—the ability to accept the world of available materials

Presented before the Third Navy Science Symposium, March 18, 1959.

Dr. Gerard is Assistant Director of Research of the College of Engineering, New York University. His interest in the minimum weight design of structures has been devoted recently to the efficient application of materials under elevated temperature conditions. In this connection, Dr. Gerard is currently serving on several technical panels of the Materials Advisory Board, National Academy of Sciences.

requires an inventive approach to the challenging demands of design.

In this vein, consider some of the successful design approaches which have led to significant advances in air vehicle performance during the past decade:

(1) Turbojet engines—the demand for higher turbine blade temperatures solved by design of afterburners.

(2) Rocket engines—the demand for higher exhaust temperatures solved by regenerative cooling design.

(3) Missile structures—the demand for high-temperature skin materials solved by design technique of utilizing heat capacity of low-density alloys.

(4) Re-entry bodies—the demand for extremely high-temperature materials solved by blunt nose aerodynamic design and also the design technique of ablation.

Admittedly, a considerable oversimplification of the facts is implied by stating that the problem is solved in any of these cases. However, progress is measured first by demonstrating feasibility and then by improving efficiency. It is in the sense that feasibility has been demonstrated that the previous problems can be considered to be solved.

It is significant to note that the solution of all of these cases involved a reduction of the first estimates of the performance demands upon materials. By pursuing the interplay between design and materials, the de-

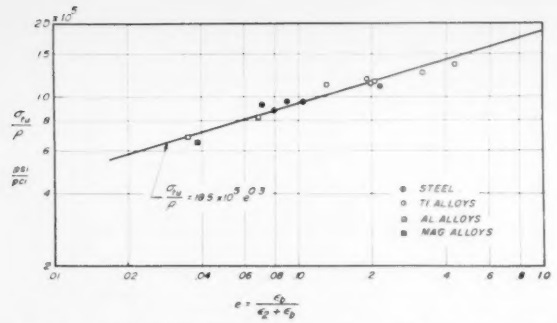

Fig. 2. Strength/weight ratio of high-strength materials as a function of ductility at room temperature.

mands upon materials were reduced to permit successful demonstration of feasibility.

As we progress in this age of great demands upon materials (in the first estimate, at least), we can anticipate that design techniques will be evolved which will reduce the demands to reasonable levels. To cope with high temperatures, limited life expectancy composite materials-structures systems of various forms are being designed. To reduce surface temperatures, aerodynamic cooling techniques such as film and transpiration designs represent promising although incompletely understood areas, at present. Completely new scientific areas such as magnetohydrodynamics may offer significant advances in reducing temperature demands upon materials.

Nature of the Interplay

When stringent demands are placed upon materials in order to achieve overall efficiency of design, it is equally important that the materials be utilized effectively. Effective utilization, however, requires much more than materials of proper mechanical and physical properties. Consider now some of the intangibles involved in a successful optimum design:

(1) Accurate knowledge of loads and other environmental conditions.

(2) Efficient design configuration of the complete structure, as well as its components.

(3) Accurate methods of structural analysis.

(4) Availability of mill products in suitable sizes to minimize jointing.

(5) Use of advanced fabrication techniques to remove excess material.

From this brief listing, it can be observed that there are many aspects to the proper selection and effective utilization of materials, particularly under severe environmental conditions. The three basic aspects are summarized in Fig. 1 which illustrates the various interactions among design, structures, and materials. In order to discuss the interplay among the three aspects in as simple a manner as possible, the following are considered: (1) design-structures interplay, (2) structures-materials interplay, (3) design-materials interplay, and (4) design-structures-materials interplay.

It must be recognized that because of these strong interactions, it is most important that the optimum design of the system be approached on an integrated basis considering simultaneously the structure, materials, and design conditions.

Structural Interplay

As illustrations of the various types of interplay depicted in Fig. 1, we shall now consider several examples.

Structures and Materials

Design Conditions: A structure subject to tensile loading containing stress concentrations of a prescribed maximum value.

Design Requirements: Find sheet material of suitable strength and ductility to achieve a minimum weight tension structure.

It can be recognized that this is the type of problem currently facing those concerned with selecting materials for solid-propellant rocket casings. An approximate approach recently presented in reference 1 defines the strength/weight ratio of tension structures in terms of the strength/weight ratio of materials and the plastic stress concentration factor as follows:

$$S/\rho = \sigma_{tu}/k_p\rho \qquad (1)$$

where

S = strength of tension structure, psi
σ_{tu} = ultimate tensile strength of materials, psi
ρ = density, pci
k_p = plastic stress concentration factor

Eq. (1) recognizes that the primary difference between the strength of tension structures as distinct from the tensile strength of materials is intimately associated with the presence of stress concentrations in the former. Stress concentrations arise both at structural discontinuities and inevitably as a result of fabrication of the structure from pieces of material.

The relative importance of stress concentrations upon the strength of structures depends directly upon ductility. The greater the ductility, the greater the reduction of the stress concentration from its elastic value as the strain is increased in the plastic range.

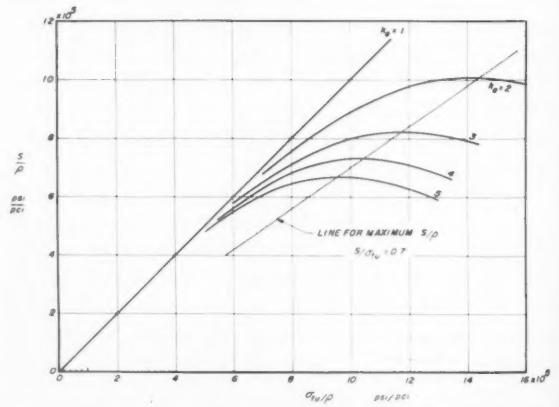

Fig. 3. Strength/weight ratio of uniaxial tension structures as a function of strength/weight ratio of materials.

An approximate relation between the plastic k_p and elastic k_e stress concentration factors for a wide variety of geometrical discontinuities is given by

$$k_p = 1 + (k_e - 1)e \qquad (2)$$

where

$e = \epsilon_b/(\epsilon_2 + \epsilon_b)$
ϵ_b = brittle strain, $\epsilon_b = \sigma_{tu}/E$
ϵ_2 = 2-in. gage length ductility

It can be observed from Eq. (2) that as e approaches zero as in the case of ductile materials, k_p approaches unity implying negligible stress concentration effects. For brittle materials, on the other hand, $e = 1$ and $k_p = k_e$ which is the elastic stress concentration factor.

In order to combine Eqs. (1) and (2), it is necessary to relate the ductility ratio e and tensile strength. This has been done in Fig. 2 for a variety of the high-strength sheet steels, titanium, aluminum, and magnesium alloys. It is most convenient that the strength/weight ratio and ductility ratio are related in the following form within ±10 per cent limits:

$$\sigma_{tu}/\rho = 18.5 \times 10^5\, e^{0.3} \qquad (3)$$

By substituting Eqs. (3) and (2) into Eq. (1):

$$\frac{S}{\rho} = \frac{(\sigma_{tu}/\rho)}{[1 + (k_e - 1)\,(\sigma_{tu}/18.5 \times 10^5\,\rho)^{1/0.3}]} \qquad (4)$$

Results obtained from Eq. (4) for prescribed values of k_e are shown in Fig. 3. It is most interesting to observe that significant reductions in structural strength are associated with σ_{tu}/ρ values greater than roughly 8 to 10 × 10^5. This is beyond the range of the high-strength aluminum and magnesium sheet alloys, and therefore stress concentrations would not be expected to have a significant influence on the strength of structures fabricated of these materials. However, this figure constitutes the lower limit for the high-strength titanium alloys and steels, and it can be expected that stress concentrations will have a significant effect here.

Furthermore, for each elastic stress concentration factor, the structural strength reaches a maximum and then begins to decline with further increases in the strength/weight ratio of materials. This is indicative

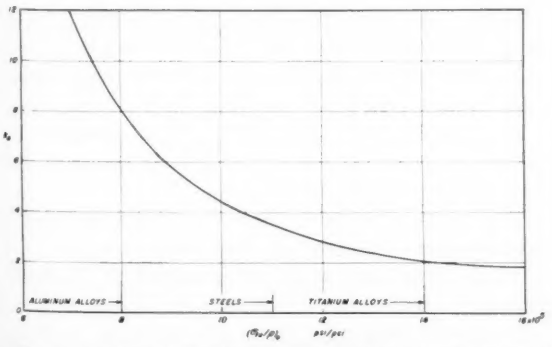

Fig. 4. Maximum elastic stress concentration factor that can be tolerated to achieve maximum strength/weight ratio of structures, as a function of strength/weight ratio of materials.

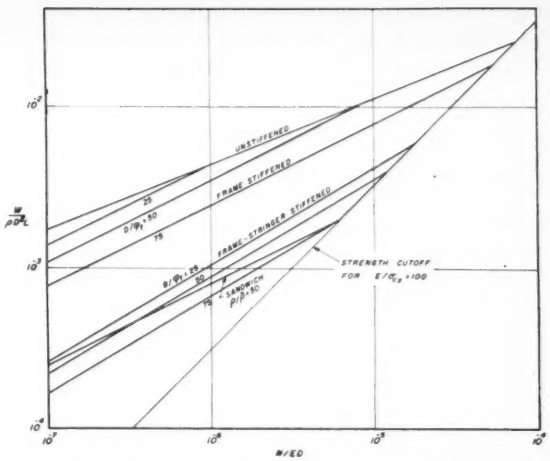

Fig. 5. Configuration efficiencies of various forms of stiffened cylinder construction under compression.

of an optimum strength/weight level and associated ductility ratio. To indicate the tolerance of a given material to the elastic stress concentration factor, Fig. 4 shows the optimum σ_{tu}/ρ. Values of σ_{tu}/ρ beyond those shown in Fig. 4 at a given k_e result in a decrease in S/ρ. Thus we have an appreciation of the interplay between structures as represented by k_e and materials as represented by σ_{tu}/ρ.

Design and Structures

Design Conditions: A cylindrical shell structure of diameter D subject to a compressive loading of N (lbs./in.).

Design Requirements: Find the proper skin-stiffening system configuration to achieve a minimum weight compression structure.

Cylindrical shell structures comprise the major portion of aircraft fuselages and missile and space vehicle components. Such shell structures are subject to compressive, bending, and shear loads generally of a relatively low magnitude. In the interests of achieving minimum weight designs, thin sheet outer skins are generally employed in conjunction with stiffening systems of various types. There is a considerable variety of skin-stiffener designs, and therefore it is of interest to investigate the interplay between the design conditions and possible structural configurations to achieve minimum weight.

The theory of minimum weight analysis of composite shell structures has been fairly well developed. For present purposes, it is perhaps sufficient to present some of the results of such analyses.

The starting point in a minimum weight analysis of a stiffened cylinder subject to compression, for example, utilizes the design conditions in terms of a loading index N/D. The weight of each stiffened shell configuration is evaluated relative to that of a solid cylinder of the same length and outer diameter. Because of the necessity of satisfying the design conditions given by N/D, the optimum stress level σ_0 is determined directly

from the analysis and often may be considerably below the compressive yield strength for a given configuration.

The results of minimum weight analyses generally can be expressed in the following forms:

$$W/\rho D^2 L = C(N/ED)^m \text{ for } \sigma_0 < \sigma_{cy} \quad (5)$$

$$W/\rho D^2 L = \pi(E/\sigma_{cy})\ (N/ED) \text{ for } \sigma_0 \geq \sigma_{cy} \quad (6)$$

where

W = weight, lbs.
D = diameter, in.
L = length, in.
E = elastic modulus, psi
σ_0 = optimum stress, psi
σ_{cy} = compressive yield strength, psi
C = coefficient determined from analysis
m = exponent, generally $0.40 \leq m \leq 0.60$

In Fig. 5, the results of a minimum weight analysis of circular cylinders under compression are shown as taken from reference 1. It can be observed that there is a significant difference in the weight efficiency of frame-stiffened and unstiffened cylinders as compared to frame-stringer stiffened and sandwich shells. Thus, in choosing the minimum weight structure, it is apparent that there is a significant interplay between the design conditions and the structural configuration.

Design and Materials

Design Conditions: A cylindrical shell structure subject to a loading index of N/D with a prescribed skin-stiffening system.

Design Requirements: Find the proper material to achieve a minimum weight compression structure.

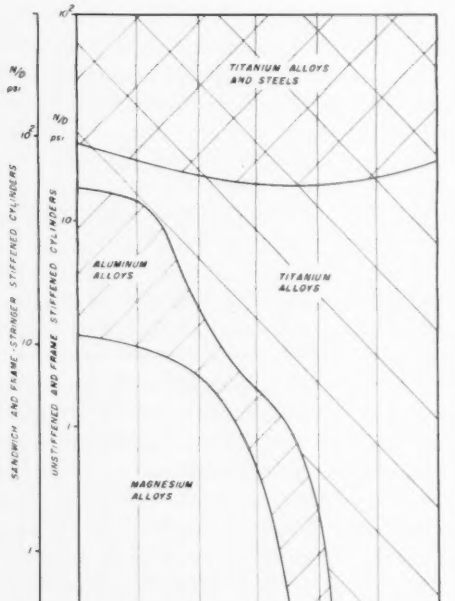

Fig. 6. Material efficiencies for stiffened cylinder construction under compression.

From an analysis such as presented in the preceding section which describes the design-structures interplay, an efficient skin-stiffener configuration can be chosen. With the selection of this configuration for a particular design, an interplay now develops between the design conditions and the material to be selected to achieve a minimum weight structure.

Again, the theory in this area has been fairly well developed, and we shall merely summarize some results available in reference 1. For the purposes of material selection, Eqs. (5) and (6) are rewritten in the following forms:

$$W/D^2 L = C(\rho/E^m)\ (N/D)^m \quad \text{for } \sigma_0 < \sigma_{cy} \quad (7)$$

$$W/D^2 L = \pi(\rho/\sigma_{cy})\ (N/D) \quad \text{for } \sigma_0 \geq \sigma_{cy} \quad (8)$$

Thus the material selection criteria are ρ/E^m for buckling and ρ/σ_{cy} for strength considerations.

By following the approach presented in reference 2 and extending it to high-strength steels and titanium alloys, the results presented in Fig. 6 are obtained. Because of a relatively small influence of ρ/E^m for the various cases considered, the results apply approximately to the various stiffened cylinders by a suitable change of the N/D scale.

In Fig. 6, it can be observed that the low-density alloys of aluminum and magnesium have a fairly wide temperature range of application at low values of structural index. The titanium alloys have a wide range of application at the higher temperature and also at lower temperatures for higher values of structural index. The steels do not appear to be attractive in these applications because of their unfavorable ρ/E^m values as compared to the other alloys. Only at high values of loading index when the parameter ρ/σ_{cy} governs do they become competitive with the titanium alloys.

Beryllium is not shown in Fig. 6 for a simple reason. If it were, it would replace all the other materials by virtue of superior values of ρ/E^m and ρ/σ_{cy}. From a compressive stability standpoint, beryllium has much to offer.

Design and Materials

As a final example of the interplay that can exist between design conditions and material selection we shall consider the transient aerodynamic heating of an exposed missile skin. Here the skin is used to transmit mechanical loads and, at the same time, acts as a "heat sink" by absorbing the boundary-layer generated heat. Thus we have the following situation:

Design Conditions: The outer skin of a missile subject to a loading of N (lbs./in.) and an adiabatic wall temperature T_{aw} for time τ.

Design Requirements: Find the proper material to achieve a minimum weight structure.

Aerodynamic heating of a thin skin obeys the following relationship:

$$T/T_{aw} = 1 - e^{-h\tau/\rho C t_s} \quad (9)$$

where

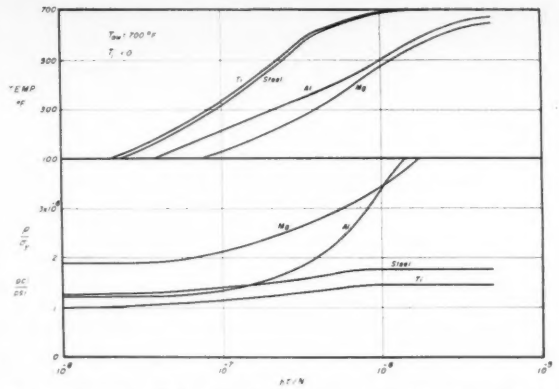

Fig. 7. Material efficiencies and skin temperatures for various materials under transient heating conditions.

T = skin temperature
h = heat-transfer coefficient
c = specific heat
t_s = skin thickness

When the skin is designed to the yield strength, then

$$t_s = N/\sigma_y \tag{10}$$

By substituting Eq. (10) into Eq. (9)

$$T/T_{aw} = 1 - e^{-(\sigma_y/\rho c)(h\tau/N)} \tag{11}$$

An examination of Eq. (11) reveals that the material efficiency criterion in this application is $\sigma_y/\rho c$, whereas the pertinent loading parameter is $h\tau/N$.

Eq. (11) has been investigated for various magnesium, aluminum, and titanium alloys and steels for the specific case of $T_{aw} = 700°F$. The results are shown in two forms in Fig. 7. The upper portion indicates that, at a specific value of $h\tau/N$, the lighter alloys are at considerably lower temperatures than the heavier alloys. This is a result of the greater specific heat and larger thicknesses required for the lighter alloys to carry the same loading.

The lower portion of Fig. 7 indicates the weight/-strength ratio of the various materials as a function of the loading parameter. It can be observed that the titanium alloys are generally superior to the others. Aluminum alloys are essentially equal to the steels up to a certain value of $h\tau/N$. Beyond this point the aluminum alloys are no longer efficient.

The interesting point in this example as in the previous ones is that, by incorporating the interplay between the design conditions and the design requirements into a proper analysis, we are presented with the data from which the minimum weight design can be readily ascertained.

Thermal Protection Systems

The various examples cited in the previous section involved in each case an interplay of two elements of the design complex illustrated in Fig. 1. In considering thermal protection systems for extreme temperature environments, it is essential that we now focus our attention upon the center of Fig. 1 which involves an interplay of the three components simultaneously—design, structures, and materials.

Design Functions

The optimum design of thermal protection systems is too complex to discuss in analytical form at the current stage of development. Consequently, we shall proceed by considering the following design functions to be performed by a structure exposed to severe aerodynamic heating of a transient or steady-state nature—load transmission, environmental protection, and contouring.

In a conventional approach, all three functions would be satisfied by use of a homogeneous structure. Under severe thermal conditions, it becomes more difficult to perform the three functions in a homogeneous structure, and overall efficiency can be achieved by splitting the functions among components of a composite system. Thus thermal protection systems emerge as interesting candidates for efficiently coping with environmental extremes. In this case, the interplay among design, structures, and materials plays a most significant role.

Various schemes have been proposed and utilized for transient and steady-state heating situations. In a broad sense, however, they may be categorized and considered in terms of the three design functions discussed previously, as shown in Table 1.

System Concepts

The "hot" structure approach is essentially the conventional one in which the three functions are satisfied simultaneously. The unconventional element here, of course, is that beyond approximately 1,800°F. the superalloys can no longer be utilized and one must turn to refractory metals and ceramics. The current research effort on such materials is to a large measure in response to this requirement.

Aerodynamic cooling is a thermal protection technique of an essentially nonstructural nature involving boundary-layer modification by mass transfer of gaseous or liquid coolants. This approach has interesting possibilities of eliminating severe temperature requirements for structural materials. However, the efficiency of aerodynamic cooling techniques relative to absorptive and radiative schemes in terms of overall system weights is incompletely understood at present.

Table 1. Thermal Protection Systems

System	Environmental Protection	Contouring	Load Transmission
"Hot" structure	← structure		→
Aerodynamic cooling (mass transfer)	coolant ←	→	← structure →
Absorptive (transient)	ablation or heat sink ←	→	← insulated substructure →
Radiative (steady state)	radiation shields ←	→	← insulated substructure →

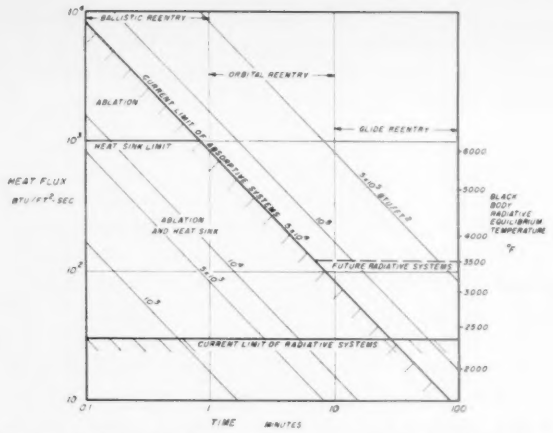

Fig. 8. **Regions of application of various types of thermal protection systems.**

It is clear, however, that aerodynamic cooling constitutes an approach of interesting potential.

Absorptive thermal protection systems utilizing ablative or heat sink techniques are essentially capable of absorbing a certain maximum amount of heat per unit area. Consequently, they are time limited although not temperature (or heat flux) limited. Because of this inherent feature, such systems are particularly attractive for the extreme thermal environments of short duration associated with ballistic re-entry bodies as shown in Fig. 8. The absorptive approach appears to retain its attractiveness under orbital re-entry conditions up to approximately 10 min. However, because such systems are inherently time limited, they do not appear to be particularly attractive in the region of glide re-entry.

Radiative thermal protection techniques generally employ a radiation shield at the outer surface backed up by an insulated or insulated and cooled structure. Because they operate primarily on radiation principles, they are basically temperature (or heat flux) limited although not time limited (excluding rapid oxidation). As such, radiative thermal protection techniques are particularly attractive for application in the glide re-entry area of Fig. 8. From a weight standpoint, they currently offer distinct advantages over all other approaches in the glide re-entry area. The ability to sustain the higher temperatures shown in Fig. 8 with this technique depends essentially upon the development of thin gage (less than 0.010 in.) refractory metal or ceramic radiation shields.

The Interplay

It is apparent that, for absorptive and radiative thermal protection systems, the interplay that first develops involves an optimum separation or splitting of the design functions. The environmental protection, contouring, and load transmission functions are then individually satisfied by pursuing the interplay among design, structures, and materials to achieve an optimum design.

At present, such composite materials-structures systems are essentially layered designs in which each of the functions are satisfied more or less individually. There is much to be gained by intelligent application of this approach. Ultimately, we may envision the composite system as a heterogeneous solid possessing the desired variable mechanical and physical properties through the thickness which will simultaneously satisfy all of the design functions.

It may be safely concluded that we are entering an era of composite structures-materials systems. To achieve notable success in this area requires an interplay on a level higher than discussed herein—an interplay among designers, structures engineers, and metallurgical and materials engineers.

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[1] Gerard, G., *Some Structural Aspects of Orbital Flight*, American Rocket Society Preprint 729–58, Nov., 1958.

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Proceedings Available

The National Midwestern Meeting—Weapons System Management Proceedings (November 7, 8, 1957) contains all ***unclassified*** papers presented at the meeting.

Member Price: $1.50 **Nonmember Price: $2.50**

The Proceedings of the National Specialists Meeting on Dynamics and Aeroelasticity (November 6, 7, 1958) contains all ***unclassified*** papers presented at the meeting.

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Special Publications Dept., Institute of the Aeronautical Sciences, Inc., 2 East 64th St., New York 21, N.Y.

This paper presents the results of a quantitative analysis of the practical limits of aerodynamic flight within the atmosphere. The cruising vehicle flight regime and the aerospace vehicle flight regime are defined and analyzed. The fundamental equations relating to these limits are derived and analyzed.

Design curves which should be of use in preliminary design and performance estimates are also presented. Although there is some overlap between the two flight regimes, each is seen to exhibit characteristics peculiar to the mode of operation which takes place within their respective limits.

A Quantitative Analysis of the Characteristics and Limitations of

Aerodynamic Flight Within the Atmosphere

Part I—Characteristics

William Chester Walter, AFIAS

Avro Aircraft Limited, Canada

Introduction

In the past half century, since man first realized his dream of powered flight, it has become very apparent that, because of the characteristics of the earth's atmosphere, some altitude limit exists above which aerodynamic flight is not practicable for sustained periods. Until recently, most practical flying such as is conducted in the field of commercial and military aviation has been confined to the lower—relatively denser—layers of the atmosphere, and therefore a quantitative analysis of this limit has not been considered of very great importance. However, the trend in military aviation toward flying higher, faster, and farther, coupled with the ever-increasing development time required for modern Air Force weapon systems, makes a more detailed determination of this limit not only desirable but imperative.

In 1956 a paper by Dr. Theodore von Kármán contained a reproduction of a diagram made by Masson and Gazley of the RAND Corporation which indicated the possible ranges for continuous flight in the velocity/altitude coordinate system.[1] As a qualitative measure of the overall limits of aerodynamic flight within the atmosphere, this diagram has served its purpose well, appearing many times in the technical literature. It was felt by this author, however, that a quantitative measure is needed to better identify the regions of flight within this qualitative flight envelope which are defined by vehicles performing different flight profiles.

This report treats first the characteristics and limitations of aerodynamic flight within the earth's atmosphere as it affects the cruise portion of the mission profile most typical of modern air-breathing engine vehicle flight operations. Cruising conditions were chosen for several reasons: (1) a large per cent of the total flight time of a strategic bombardment or reconnaissance mission is spent in cruising to and from the target area, and the cruise condition is also characteristic of cargo and troop carrier operations; (2) the conclusions which might be drawn from an analysis of the cruising condition which is well defined were considered to be more general than those conclusions which might be obtained from an analysis of any other flight condition; and (3) the cruise condition lends itself to a less complicated analysis than any other flight conditions which might be considered for this study. An analysis is then presented relative to the flight regime of aerospace vehicles of tomorrow compared to the cruis-

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Symbols

a	=	speed of sound, ft./sec.
C_L	=	lift coefficient, L/qS
D	=	drag, lbs.
g	=	acceleration of gravity (32.2 ft./sec.^{2})
H	=	distance from center of earth to aircraft in flight, ft.
H_r	=	average radius of earth (20.89×10^4 ft.)
h	=	geometric altitude of aircraft above earth's surface, ft.
Kc	=	proportionality factor $1/(L_A/W)$, dimensionless
L	=	lift, lbs.
M	=	Mach Number
m	=	mass, lb. sec.^{2}/ft.
q	=	dynamic pressure, lbs./ft.^{2}
R	=	range, miles
S	=	wing area, ft.^{2}
s.f.c.	=	specific fuel consumption, lb./hour/lb. thrust
T	=	thrust, lbs.
V	=	velocity, ft./sec.
W	=	weight, lbs.
ω	=	angular velocity, rad./sec.

Subscripts

A	=	aerodynamic
C	=	centrifugal
E	=	effective
F	=	fuel
f	=	final
i	=	initial

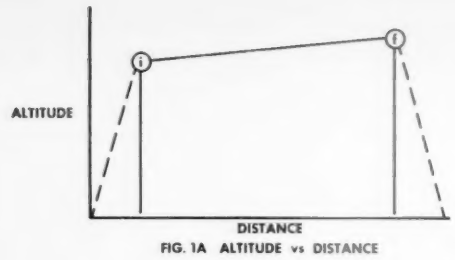

FIG. 1A ALTITUDE vs DISTANCE

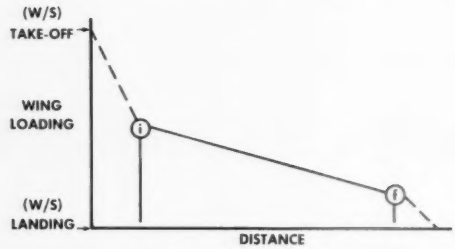

FIG. 1B WING LOADING vs DISTANCE

Fig. 1. Typical cruising vehicle mission profile.

ing flight regime. Aerospace vehicles when flying within the atmosphere have all the characteristics of aircraft. Beyond this region they become space vehicles. This class of vehicle includes hypersonic boost-glider vehicles and winged re-entry vehicles.

For the purpose of clarity, this report is divided into two parts—Part I treats the characteristics of the flight regime under investigation, and Part II (to be published in the September issue), the limitations of that flight regime.

A concerted effort was made to take into consideration the latest state of the art and, at the same time, present a conservative but realistic estimate of the characteristics and practical limits of aerodynamic flight within the earth's atmosphere.

Cruising Vehicles

Efficient cruising flight at high altitude imposes the following requirements on an aircraft which must, at least in part, depend upon aerodynamic forces to oppose the earth's gravitational attraction:

Low wing loading High specific thrust at altitude High speed	Primary Effect on Altitude
Low specific fuel consumption High L/D configuration Flight at $(L/D)_{max}$	Primary Effect on Range

The requirement for low wing loading is most clearly seen in considering the landing wing loading of such an aircraft which should certainly be as low as practicable in order that no unnecessary weight be carried to altitude. The variation of these factors and their effect on the limits under investigation are discussed in this paper.

Fig. 1A shows a typical mission profile in which the cruise portion is seen to represent a relatively large part of the total flight.

Fig. 1B illustrates the fact that in such flights a large change in wing loading occurs between the take-off and beginning of cruise and again between the initiation of cruise and end of cruise because of the fuel consumed, while the landing wing loading is only slightly less than that of the end of the cruise.

Two other factors must be considered in this analysis—centrifugal lift and the variation of the earth's gravitational field with altitude. The centrifugal lift is the additional lift afforded a vehicle traveling at extreme speed around the curvature of the earth due to centrifugal force which is in addition to the aerodynamic lift provided by the aircraft lifting surfaces. The variation in the earth's gravitational field was found to have a negligible effect upon the results of this study for the altitudes considered, and therefore this parameter was not included in the calculations. Centrifugal lift, however, has a profound influence on the characteristics and limitations of sustained flight, as will be shown in the analysis which follows. The entire analysis is based on the assumption of a nonrotating earth.

Centrifugal Lift Contribution

For unaccelerated level flight:

$$L_E = L_A + L_C = W$$

$$L_E/W = (L_A/W) + (L_C/W) = 1$$

but

$$L_C = mH\omega^2$$

$$L_C = (W/g)H\omega^2$$

$$V = \omega H$$

$$M = V/a$$

$$\omega^2 = M^2a^2/H^2$$

where

$$H = H_r + h$$

$$L_C/W = M^2a^2/gH \qquad (1)$$

$$L_A/W = 1 - (L_C/W) \qquad (2)$$

Eq. (1) is the nondimensionalized equation for centrifugal lift, which is directly proportional to the square

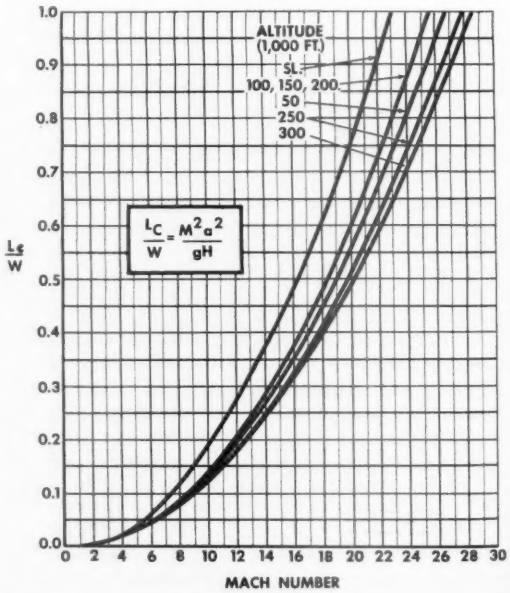

Fig. 2. Centrifugal lift to weight ratio vs. Mach Number.

of the flight velocity and inversely proportional to the product of the distance of the aircraft from the center of the earth and the acceleration of gravity. Eq. (2) shows that the aerodynamic lift to weight ratio for any aircraft in unaccelerated level flight is equal to one minus the centrifugal lift to weight ratio.

Fig. 2 is a plot of L_C/W vs. Mach Number with altitude as a parameter from Eq. (1). It may be seen immediately that altitude has an effect on this expression. This altitude effect is twofold—one contribution arising because of the distance term H, and the other due to the variation of temperature with altitude which governs the a^2 term. It is because of this temperature effect that there is a reversal in the sequence of the curves between 50,000 and 250,000 ft. altitude and that the curves from 100,000 to 200,000 ft. coincide. At 100,000 ft. and Mach 18, the support of a winged vehicle in level unaccelerated flight is approximately evenly divided between centrifugal and aerodynamic lift. At Mach 8 and 100,000 ft., approximately 10 per cent of the lift on the vehicle is centrifugal.

Fig. 3 is a plot of Eq. (2) showing the variation of aerodynamic lift to weight ratio with altitude and Mach Number for unaccelerated level flight.

A relation for centrifugal lift having been established, its effect on cruising flight may be investigated.

Effect of Centrifugal Lift on Wing Loading

$$L_E = L_A + L_C = C_L qS + (WM^2a^2/gH)$$

For unaccelerated level flight:

$$L_E/W = C_L q(S/W) + (M^2a^2/gH) = 1$$

$$C_L q(S/W) = 1 - (M^2a^2/gH)$$

$$W/S = C_L q/(1 - L_C/W)$$

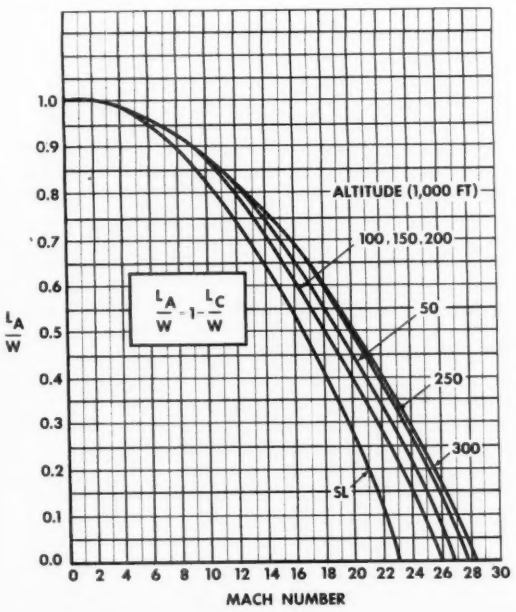

Fig. 3. Aerodynamic lift to weight ratio vs. Mach Number.

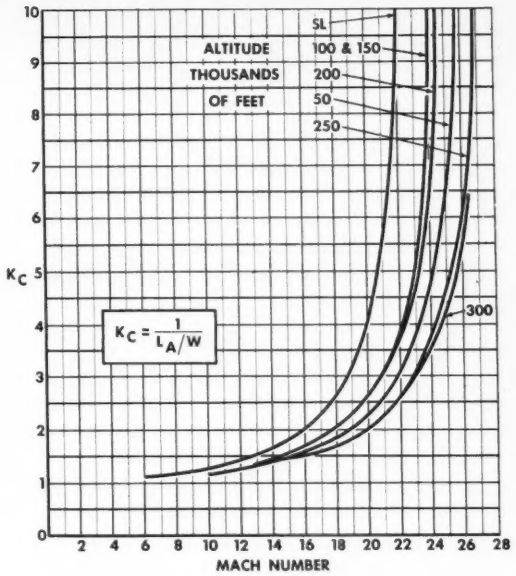

Fig. 4. K_C vs. Mach Number.

$$W/S = C_L q/(L_A/W) \quad (3)$$

$$K_C = 1/(L_A/W) \quad (4)$$

$$W/S = K_C C_L q \quad (5)$$

Eq. (3) shows aircraft wing loading to be directly proportional to the product of the coefficient of lift and dynamic pressure and inversely proportional to the aerodynamic lift to weight ratio. It can be seen from Eq. (2) that wing loading is a function of centrifugal lift, but for ease of computation the expression is left in terms of aerodynamic lift. Eq. (4) presents the effect of centrifugal lift on wing loading in the form of a proportionality factor defined as K_C. Fig. 4 shows the variation of K_C with altitude and Mach Number; again the profound effect of centrifugal lift with increasing Mach Number should be noted.

The key to the practical limits of cruising flight lies in the selection of the values of C_L used in Eq. (5) which will be discussed in Part II.

Effect of Centrifugal Lift on L/D

For unaccelerated level flight:

$$L_E = L_A + L_C = W$$

$$L_E/D = (L_A/D) + (L_C/D)$$

$$(L/D)_{E max} = (L/D)_{A max} + (L/D)_C$$

(for a given Mach Number)

In free flight at $(L/D)_{A max}$ the aircraft is allowed to seek an equilibrium altitude such that $L_A + L_C = W$.

$$(L/D)_C = (L_C/L_A)\,(L/D)_A \quad (6)$$

$$(L/D)_C = (K_C)\,(L_C/W)\,(L/D)_A \quad (7)$$

Then $(L/D)_{E max} = [1 + (L_C/L_A)]\,(L/D)_{A max}$

But $K_C = 1 + (L_C/L_A)$

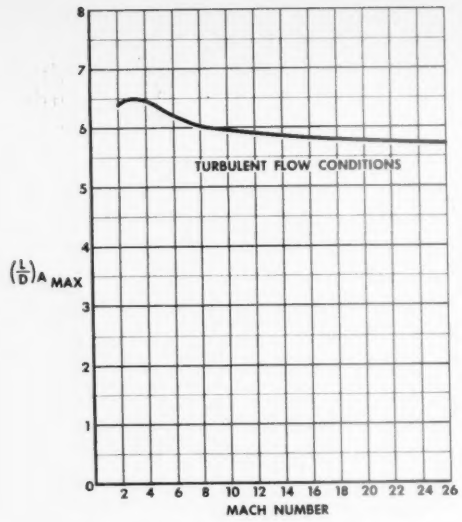

Fig. 5. **$(L/D)_{Amax}$ vs. Mach Number; typical hypersonic aircraft configuration.**

$$(L/D)_{Emax} = (K_C)\ (L/D)_{Amax} \qquad (8)$$

Thus, from Eq. (8), $(L/D)_{Emax}$ is a function of centrifugal lift times the $(L/D)_{Amax}$ of the aircraft.

But again in unaccelerated level flight:

$$(L/D)_E = W/T$$

Effect of Centrifugal Lift on *L/D* (*Cont.*)

$$T/W = 1/(L/D)_E$$

$$(T/W)_{min} = 1/(L/D)_{Emax} \qquad (9)$$

Therefore, from Eq. (9) the ratio of minimum total thrust required to aircraft weight is inversely proportional to $(L/D)_{Emax}$. Thus, at very high speeds approaching circular speeds, only an extremely small thrust is required for cruising flight.

For any given configuration the $(L/D)_{Emax}$ may be found from Eq. (8) if the $(L/D)_{Amax}$ vs. Mach Number data are available for that configuration.

High supersonic and hypersonic aerodynamic vehicles will be characterized by large fineness ratios and wings or lifting fuselages with large sweep angles.[2, 3] This holds equally true of cruising vehicles and aerospace vehicles. Fig. 5 is a plot of the $(L/D)_{Amax}$ vs. Mach Number of such a typical hypersonic configuration. Fig. 6 is a plot of the variation of $(L/D)_{Emax}$ with altitude and Mach Number for this configuration, making the effect of centrifugal lift very apparent.

The Brequet range equation for cruising flight may now be expressed as follows:

$$R = (Ma/\text{s.f.c.})\ [(L/D)_E]\ \ln\ [(W/S)_i/(W/S)_f] \qquad (10)$$

Aerospace Vehicles

Aerospace vehicles utilize their aerodynamic surfaces to extend their range, provide control within the atmosphere, and provide the capability of making a more or less conventional aircraft landing at a predetermined landing site. When operating essentially out of the atmosphere their aerodynamic shape is unimportant and the vehicle operates as a space vehicle either in orbit or in a space trajectory. For comparison with the typical cruising vehicle mission profile shown in Fig. 1, the typical aerospace vehicle mission profile is presented in Fig. 7. Fig. 7A illustrates that initiation of the orbiting or gliding phase of an aerospace vehicle begins after the completion of a rocket boost phase. The orbiting case shown is for a circular orbit, in which the mission consists of a boost phase, an orbiting phase, exit from orbit phase, a hypersonic gliding re-entry, and a landing phase. The hypersonic glider case shown is

(*Continued on page 53*)

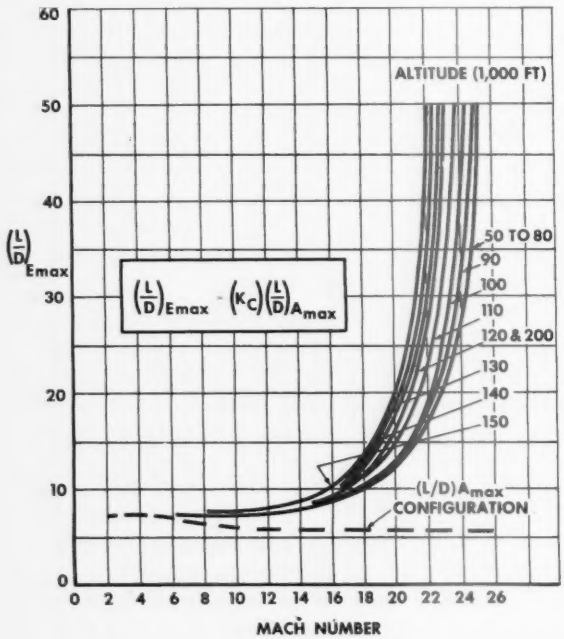

Fig. 6. **$(L/D)_{Emax}$ vs. Mach Number; typical hypersonic aircraft configuration.**

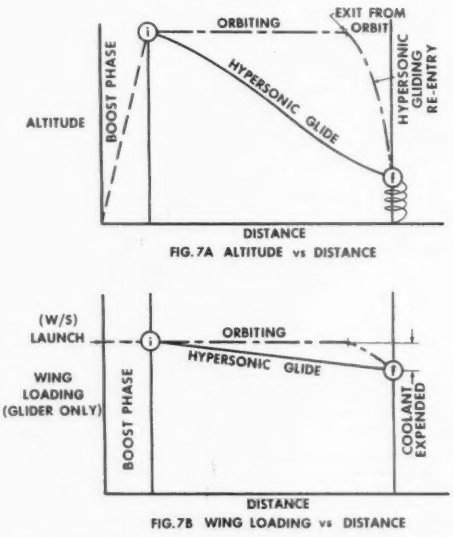

Fig. 7. **Typical aerospace vehicle mission profile.**

The parameters of fuel quantity, altitude, ambient air temperature, and wind must be taken into consideration in order to limit range prediction errors to less than 5 or 10 per cent. A diagram of a simple analog-type range computer concludes this paper.

Automatic Range Prediction in Flight

Myron A. Hoffman, AIAS
Massachusetts Institute of Technology
and
Harvey L. Pastan, MIAS
Dynamic Instrument Company, Inc.

ALTITUDE, 1,000 ft.; Mach Number, over 2; going full bore on a heading of two-zero-three on a low level mission deep into enemy territory. Can I make it back to Base Able? Just how far can I go anyway? When must I break off the mission in order to make it back at all?"

How many times have these questions crossed the minds of military pilots during the thousands of combat missions flown since the airplane was invented? And how much more critical will these questions be on future combat missions, such as the one described above?

The problem of predicting the range remaining in flight is as old as flight itself. Automatic prediction, however, is just beginning to become a reality.

Today a pilot wishing to compute range remaining in flight refers to one of several manual computing aids based on the *Flight Handbook* for his aircraft—e.g., Fig. 1—or refers to the *Flight Handbook* itself. He must read his fuel quantity remaining, compute an aircraft weight, estimate reserves, then determine the optimum cruise speed and altitude, and, finally, establish the range remaining under these conditions. All this mental juggling must be done under tension while accomplishing an important mission.

Even with the simplification incorporated in various hand computers and other manual aids, there is much to be desired when using these aids under combat conditions. The field of automatic computation seems to offer a better solution to this important problem.

An automatic computation system must exhibit certain qualities to constitute a "better solution" than present manual-plus-mental manipulations. First, it must be at least as accurate as the manual technique. The equipment must be simple, reliable, and lightweight and must produce the answer instantaneously.

Now, in order to establish what form the answer should take, a study of the specific type of aircraft involved, the mission profiles, pilot work load, and so forth should be made. This paper will concentrate on one type of situation of much immediate importance, that of a fighter or interceptor aircraft normally flown with only a single-man crew.

Much of the background for this work is based upon studies conducted for the Air Force by the Massachusetts Institute of Technology Cruise Control Project during the years 1954 through 1956 at which time the authors were members of that group.

Mr. Hoffman received his B.S. and M.S. degrees in Aeronautical Engineering in 1952 at the Massachusetts Institute of Technology. After receiving his Sc.D. degree in Instrumentation and Automatic Control in 1955 from M.I.T., he was appointed an Assistant Professor at the Institute. From 1956 to 1959, he was on a leave of absence serving in the U.S. Air Force first in the Flight Control Laboratory, WADC, and then as an R&D Staff Assistant in the DynaSoar Project Office in the ARDC Directorate of Systems Management, Wright Patterson AFB, Ohio. In July, 1959, he returned to M.I.T. to resume his duties as Assistant Professor in the Department of Aeronautics and Astronautics.

Mr. Pastan, Chief Engineer of the Dynamic Instrument Company, Inc., Cambridge, Mass., received his B.S. degree in 1949 from the Worcester Polytechnic Institute and an M.S. degree the following year from the California Institute of Technology. Subsequently, he was employed as a Research Engineer at Hughes Aircraft Company, Culver City, Calif., where he was engaged in the development and flight-test evaluation of airborne fire control systems. From 1954 through 1958, he was Project Leader of the Cruise Control Project in the Department of Aeronautical Engineering at the Massachusetts Institute of Technology. His present work is principally devoted to the development and manufacture of strain-gage types of instrumentation.

The Basic Range Equation

A typical combat mission profile for an interceptor is illustrated in Fig. 2. The profile, shown for con-

Symbols

h = altitude, ft.
K = constant
Q = fuel quantity, lbs.
R = range, nautical miles
SR = specific range in nautical miles flown per pound of fuel burned
V_T = true airspeed, knots
V_W = component of wind velocity along flight path, knots
w_f = fuel flow rate, lbs. per hour

Subscripts

(avg) = average
(cl) = climb
d = descent
(opt) = optimum
(res) = reserve

venience, represents the special case in which the pilot starts from and returns to the same base. As can be seen, a typical mission consists of many phases of flight, all of which directly or indirectly contribute to the overall range attained.

The computation of the mission radius is probably the most complicated aspect of the range performance problem. It involves estimations of time in combat, winds on both the outbound and the return leg, and many other factors difficult to predict with any degree of certainty. The pilot, of course, must make preliminary estimates during the preflight mission planning stage, but these calculations are used only as rough guides.

Actually, once on his way, the pilot thinks more in terms of his ability to return to the base assigned to him, or the closest alternate base, than he does in terms of the overall mission radius. The question he asks himself is, "When must I break away from combat to be able to make it back?" Considering only the return leg of the mission profile is thus the first important simplification to make when attempting to design a simple, lightweight, automatic computer.

In arriving at a quick range figure, the pilot usually first estimates the time remaining:

$$\text{Time Remaining} = [Q - Q_{(res)}]/w_f \qquad (1)$$

where Q is the total fuel quantity remaining, and w_f is the average fuel flow rate for the return leg of the mission. This is then multiplied by the true airspeed (or average ground speed if knowledge of the winds along the return course is available) to yield the approximate range remaining:

$$R = (V_T \pm V_W) \times [Q - Q_{(res)}]/w_f \qquad (2)$$

This can be rewritten in a slightly more convenient form:

$$R = [SR \pm (V_W/w_f)] \times [Q - Q_{(res)}] \qquad (3)$$

where $SR = (V_T/w_f)$. The specific range SR is the number of air miles flown per pound of fuel burned. This equation is actually a practical simplification of the Breguet Range Equation, where the specific range is assumed to be approximately constant at some average value instead of varying inversely with the aircraft weight.

This is essentially the relation the fighter pilot uses in flight and, as such, constitutes an excellent starting point for any discussion of range prediction. The proposed automatic computer based on Eq. (3) cannot be designed to follow exactly the same procedure which the pilot uses. For example, the pilot exercises his judgment, reading his fuel flow only after the aircraft has steadied out at the desired cruise speed and

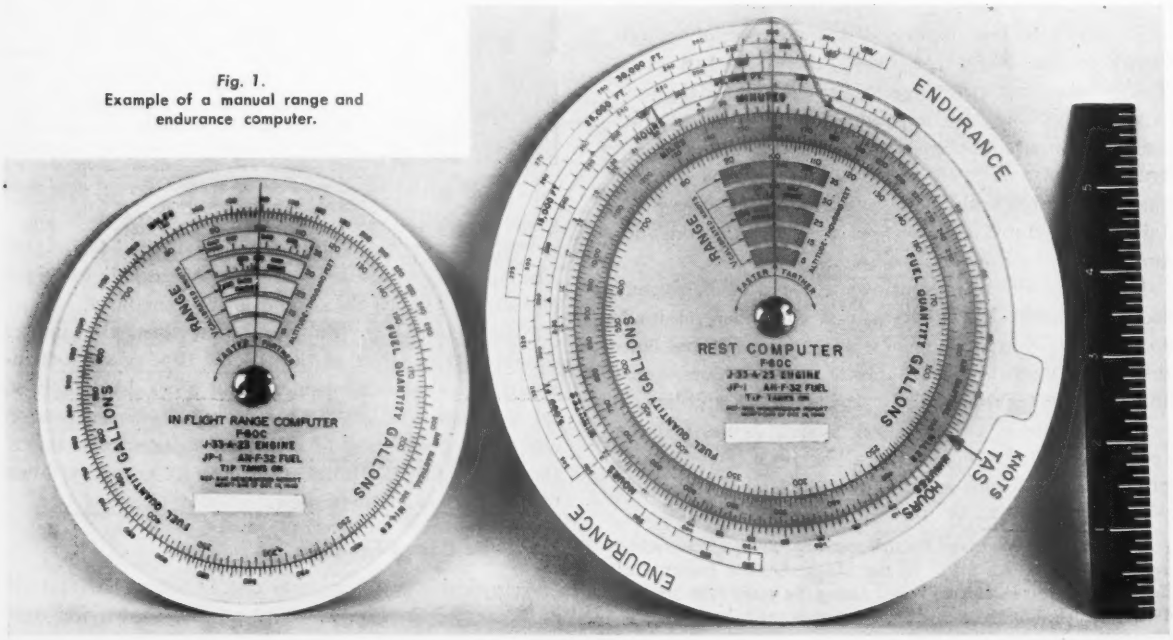

Fig. 1.
Example of a manual range and endurance computer.

altitude. He knows that the fuel flow reading is meaningless as far as a range computation is concerned during accelerations and other transient conditions. In addition, when the pilot adjusts the reserve fuel quantity, he subtracts from the total reading according to the conditions at hand—including weather, fatigue, and the like—and tailors his margin of safety to fit his current state of mind, so to speak.

If this automatic computer is to be truly automatic, it cannot require numerous input settings by the pilot. Therefore, a compromise solution in the selection of input parameters for the computer must often be sought. The simplest computer based on this equation would be one which solved only for the optimum range. In this case, the parameter SR is selected as the average value for a return cruise at the optimum cruise conditions. It is then stored as a constant in the computer.

The parameter Q is fed into the computer electrically from the fuel quantity totalizing instrumentation. The parameter $Q_{(res)}$ represents the estimate of the fuel required to descend and to make a standard penetration, approach and landing, and at least one go-around. This can also be stored as a constant in the simple computer. In order to eliminate the necessity for any manual settings by the pilot, the wind estimate will be eliminated in what shall be called the "Minimum Size Range Computer" or, more simply, the "Minimum Computer."

The resulting equation solved by this Minimum Computer is:

$$\left.\begin{aligned} R_{(opt)} &= (K_1)\,(Q - K_2) \\ K_1 &= SR_{(avg)} \\ K_2 &= Q_{(res)} \end{aligned}\right\} \qquad (4)$$

However, as will be seen in the next section, this equation for the Minimum Computer is inadequate because the above computation has several deficiencies, some of significant proportions. In order to determine which additional factors are important, a study of the errors involved in this simplified equation is required.

Error Analysis

The sources of error in Eq. (4) may be classified as flight profile, configuration, random, and computation. The following discussion will consider the errors from two points of view—the pilot's manual computation and the automatic computation based on essentially the same equation.

The values of the errors in range prediction were obtained from extensive analysis of several current interceptors. However, only average values will be used in order to keep the discussion unclassified.

Flight Profile Effects

The range prediction, whether made by the pilot or by a computer, will be accurate only if the assumed flight profile is adhered to quite closely. In the case of this typical interceptor, the prediction has been restricted to the return leg of the mission. To achieve

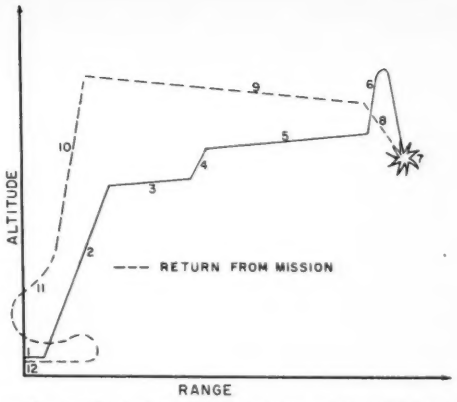

Fig. 2. Typical interceptor mission profile: (1) Taxi, take-off, accelerate; (2) climb; (3) cruise; (4) drop tanks and climb; (5) cruise; (6) climb and accelerate; (7) combat; (8) climb; (9) cruise; (10) descend; (11) penetration and landing; (12) reserve—25 min. at s.l.

the range predicted, the pilot must start a maximum range cruise immediately, a descent at the proper distance out, and, finally, a standard penetration and landing. If the pilot deviates from this assumed profile or if circumstances or environment cause some deviation, the range prediction will be in error.

The maximum range cruise path for current interceptors is usually along the cruise ceiling.[1] This is defined by the Air Force as the maximum altitude at which the pilot can still climb at 300 ft. per min. at his present weight with the throttle left at the maximum continuous cruise power setting (without afterburning). As the aircraft weight decreases, the cruise ceiling altitude increases, resulting in a gradually climbing path.

The optimum cruise Mach Number is essentially a constant independent of aircraft weight and determined almost exclusively by the drag rise—that is, the optimum cruise Mach Number is fixed at a value just below the point where the drag rise becomes important since the cruise efficiency rapidly deteriorates if the aircraft is flown above this Mach Number.[1–3]

Usually the pilot has direct control over the cruise conditions selected and will generally try to fly the optimum cruise path and optimum cruise Mach Number if the fuel remaining is an important consideration at the time. Otherwise, he may simply cruise at some convenient constant altitude and the corresponding best Mach Number for his present aircraft weight.

Typical figures for the decrease in the range of a fighter aircraft due to flying an off-optimum Mach Number are shown in Fig. 3a. For example, cruising at a Mach Number only 0.05 above the optimum can result in a 4 to 9 per cent decrease in range. Furthermore, if the pilot flies at a constant altitude below the cruise ceiling, the range is decreased as shown in Fig. 3b. For example, cruising about 5,000 ft. below the cruise ceiling results in about a 5 per cent decrease in range.

These figures illustrate that the optimum cruise profile must be adhered to rather accurately if optimum range performance is to be realized. Both the

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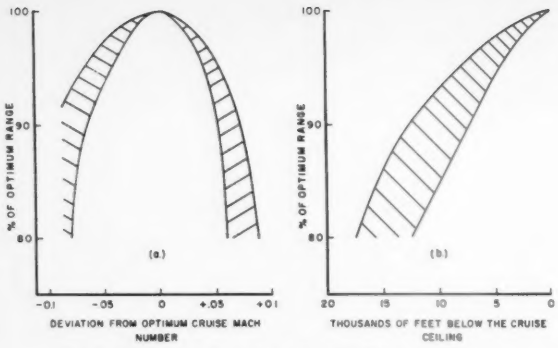

Fig. 3. The effect of varying cruise conditions upon range.

pilot's estimate and the range computer's answer will be in error if the cruise conditions deviate from the optimum.

Another way in which the flight profile can deviate from the one described above occurs if the pilot comes out of combat at an altitude considerably below the optimum cruise path. As shown in Fig. 4a, an emergence at about 15,000 ft. below the cruise ceiling will cause an 8 per cent loss in range. This is a large enough effect to require the inclusion of a climb term in the range equation. The climb fuel and range can be represented with excellent accuracy by approximations of the type shown in Fig. 4b.

A further complication can arise if the pilot is very low on fuel, as well as being at a low altitude initially. However, this is generally an emergency situation and will require that the pilot employ some other means to cope with this problem. No attempt will be made to have the computer handle this situation since the complexity of the mechanization required would defeat the purpose of the design.

The descent profile is also subject to variations from the typical one selected. For example, if a minimum time descent is used, less overall ground miles will be covered per pound of fuel used than if a maximum range descent were used. This could be serious if fuel is low, but we must rely on the pilot to have the good judgment to use the descent appropriate to the situation at hand.

Configuration Effects

Configuration effects include both the drag and weight condition of the airframe. If the data used by the pilot or computer are based on the clean configuration, flying with external tanks can cause the range prediction to be in error by 10 per cent or more. However, it is assumed that the pilot will drop his tanks on the return leg if range is a critical factor.

It is important to make a judicious choice of the value of $SR_{(arg)}^{*}$ stored in the computer. The selection should be based on the more critical missions—that is, the maximum radius missions. If the pilot comes out of a short combat heavier than normal due to the greater fuel remaining, the $SR_{(arg)}^{*}$ figure will be too high, and hence the range prediction will be in error on the high side. However, the error is not large; about 20 per cent more fuel will cause the range prediction to be only 1 per cent too large. Therefore, a careful selection of the $SR_{(arg)}^{*}$ will cause these errors to be negligible.

Random Effects

Under this general category fall many items such as environmental conditions, pilot technique, variations between aircraft and engines of the same type, and so forth.

Environmental effects include wind, temperature, turbulence, and weather conditions in general. Head winds have a direct effect in reducing range obtained, the average figure being about 1 per cent range loss for each 5 knots headwind. There are also second-order effects which result in a small change in the optimum cruise speed, but these are negligible compared to the direct effect of the wind on range.

The ambient temperature at the cruise altitude also has an important effect on the range as shown in Fig. 5. For example, on a typical hot day, studies have shown that the temperature in the isothermal region may be about 15°C. above the standard day value. This will cause an appreciable reduction in the engine thrust output at maximum continuous cruise power, resulting of necessity in a lower cruise ceiling. This, in turn, results in a decrease in the cruise range obtainable by about 5 to 10 per cent for the case stated above. Neither the pilot using the present handbooks nor the computer can take this effect into consideration without more data inputs.

Atmospheric turbulence causes another random effect. The resultant throttle jockeying to keep the aircraft flying straight and level will generally result in poorer fuel consumption. In fact, pilot technique in

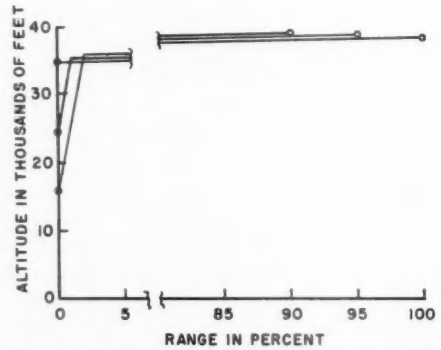

Fig. 4a. The effect of low altitude after combat on the return-to-base range.

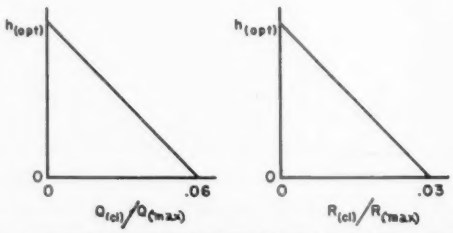

Fig. 4b. Average fuel used and range obtained in climbs to the optimum cruise altitude.

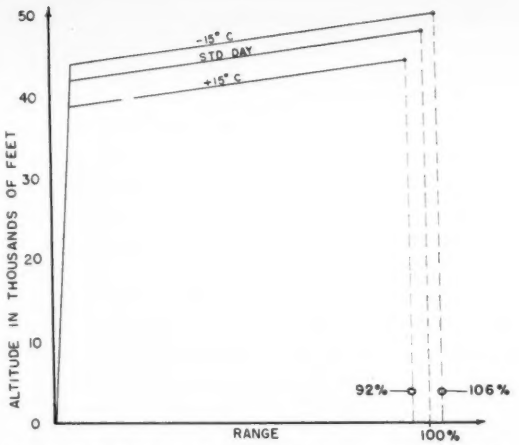

Fig. 5. Typical variation in range due to temperature at the cruise altitude.

general can have an important effect on range performance. This is clearly a random and unpredictable factor.

Other random factors include drag variations between aircraft of the same type. There has been no systematic study of this effect, but it is well known that in any given squadron there are "clean" airplanes and "dirty" airplanes. Furthermore, there are variations in the specific fuel consumptions of engines coming right off the same production line which may amount to as much as 5 per cent.

The net result of these two effects is that the fuel consumption at the optimum cruise conditions probably varies considerably between aircraft of the same type and that handbook data are only the average performance for the type. Both the pilot and the computer can account for this in only a very approximate way (by trimming up the *SR* figure used, basing the adjustment upon the experience gained with a particular aircraft).

Mechanization Effects

In order to arrive at an estimate for the remaining range, both the pilot and the computer must accept certain measured values, such as fuel quantity. This

Table 1. Summary of Errors in "Minimum Computer" Range Prediction

Cause of Error	Typical or Commonly Encountered Situation	Average Error, %*
low altitude after combat	20,000 ft.	−12
head winds	50 knots	−10
hot day	+15°C. above normal isothermal temperature	−8
configuration	external tanks left on	−15
high weight after combat	20% more fuel	−1
off-optimum Mach Number	±0.05 M	−5
cruise below optimum path	5,000 ft. below	−5
measurement inaccuracies	±3 to 5% error in fuel quantity	±4
computer inaccuracies	±2% errors	±2

* Negative errors indicate that the predicted range is greater than the range which can actually be achieved.

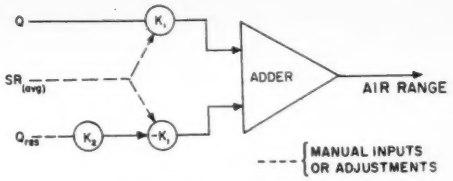

Fig. 6. "Minimum" Computer.

is a difficult quantity to measure precisely—typical installation inaccuracies run from 3 to 5 per cent.

In addition, there are computation errors which are associated with the mechanization of the equation. These should be no more than 1 or 2 per cent in a well-designed computer. Analogous computation errors for the pilot involve the difficulty in reading the *Flight Handbook* or hand computing aids and arithmetic errors which can crop up in any manual computation.

Summary of Errors

To facilitate the comparison of errors, a summary of the preceding error analysis is presented in Table 1. First the various causes of errors are listed. Then a typically encountered situation in each category is given, along with the resulting error in the range prediction.

It is readily apparent that the presence of several sources of error at the same time can rapidly reduce the usefulness of the range output of the Minimum Computer to nil.

Simple and Complicated Computers

It would appear from the foregoing discussion that the accurate prediction of range remaining in flight is a difficult if not impossible task. However, it is to be noted that in effect the same pitfalls face the pilot as are troublesome in an automatic computation scheme.

The pilot's practical approach to the solution of this problem has been to keep the computation simple and to allow a healthy reserve. The Minimum Computer using the simple expression for range in Eq. (4) can be designed on the same basis. A block diagram of the Minimum Computer is shown in Fig. 6. It can be seen to be extremely simple, involving no more than a subtraction and a scale factor change. In fact, the fuel quantity totalizing indicator could simply be renumbered in terms of miles of range remaining instead of pounds of fuel remaining, a proposal set forth several times.

While the simplicity of this Minimum Computer is appealing, it cannot be considered much of an advance over present manual techniques. An accuracy of ±10 to 25 per cent is about all that could be expected on the average. This would dictate the choice of a very large reserve to cover the case where the errors add to give a predicted range 25 per cent greater than is actually obtainable. More important, however, is the fact that the pilot would have little faith in the indication and would probably prefer to calculate the range himself for then, at least, he would know the degree of approximation.

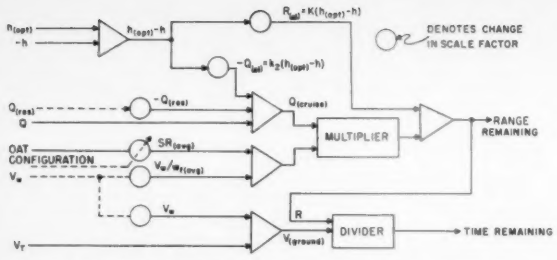

Fig. 7. **Block diagram of a range and endurance computer.**

It is evident that, to be of real value, the automatic range computation must be accurate to at least within ±5 to 10 per cent. A study of the possible sources of error (Table 1) indicates that several correction terms must be added to the basic equation to achieve this accuracy.

One basic limitation on the obtainable accuracy is the error in the fuel quantity measurement. Extensive work in this area has reduced the measurement error to at best 3 to 5 per cent for service aircraft. Both the pilot and the automatic computer must live with this situation. Therefore, it appears necessary to allow about ±5 per cent for measurement, computation, and mechanization errors alone.

In order to have reasonable assurance that the sum of all the other errors will be less than ±5 per cent a large percentage of the time, we must attempt to correct for all effects which have a high probability of contributing more than about ±2 per cent error. These corrections include climb correction, wind correction, temperature correction, and configuration selection. The corrected equation then becomes

$$R_{(opt)} = \{SR_{(avg)} \pm [V_W/w_{f(avg)}]\} \times [Q - Q_{(cl)} - Q_{(res)}] + R_{(cl)} + R_d \quad (5)$$

The block diagram for a computer which incorporates these correction features is shown in Fig. 7. The climb correction can be based solely on present altitude with good accuracy (see Fig. 4b). The wind correction is applied only to the cruise term for simplicity, and only the wind component along the assumed return track is used. If Doppler radar is available, this is by far the best source of wind information. It must be recognized, however, that the wind correction term does not yield the right answer until the cruise altitudes are reached. There is no simple way to correct automatically for the case when the aircraft is at lower altitudes.

The temperature correction to the average specific range is based on the present ambient temperature and is also in error when the aircraft is at low altitudes. The pilot must recognize the fact that the range prediction will improve in accuracy as he approaches the cruise altitudes, whether he estimates the range remaining or has it computed automatically for him.

The configuration selection knob can be considered to be optional because the aircraft will almost invariably return from a mission in the clean configuration, particularly if fuel is low. Similarly, a reasonable reserve figure can usually be agreed upon by all the operational commands concerned so that provision of a selection knob for this parameter is also considered optional.

One refinement not included in the version of the computer in Fig. 7 is the mechanization of specific range as a function of gross weight. As has been pointed out, the specific range increases as the weight decreases. However, the errors incurred by assuming an average value for specific range are very small for interceptors since the change in weight on the return leg is quite limited. This correction term may be necessary if this range computation scheme is applied to other types of aircraft.

One further degree of sophistication in our range computer development would be the inclusion of a cruise mode selection. In addition to the optimum range mode, provision would be made for computing the best range at any selected cruise altitude. (The assumption is made that the pilot would fly the best Mach Number for his present weight at this selected altitude.) The additional mode would add great flexibility to the computer, allowing the pilot to select his cruise conditions to fit the circumstances and still retain an indication of range remaining. This is often referred to as the "present range" mode as contrasted to the "optimum range" mode discussed throughout most of this paper.

Related Problems

Up to this point, only the problem of computing range and time remaining has been considered. An equally important cruise control function is the indication of the optimum cruise conditions. Simple cruise data storage instruments have been designed and constructed for operation in turbojet-powered aircraft. One version of such a system displays the optimum cruise Mach Number and engine pressure ratio on the same indicators with the actual values of these parameters. Also displayed is the deviation of the present altitude from the optimum cruise altitude. Best cruise at constant altitude or constant Mach Number are additional modes provided. It is logical to combine the range computer with the cruise control computer where both functions are required because parameters such as total fuel weight, deviation from the optimum cruise

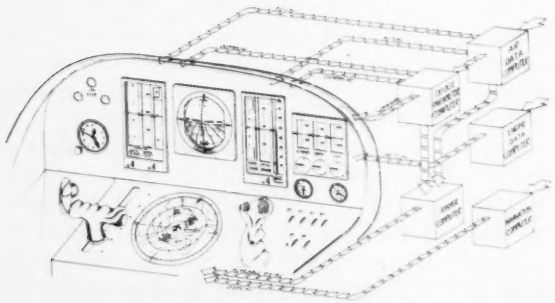

Fig. 8. **Integrated instrument system.**

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altitude, ambient air temperature, and aircraft configuration are common to both.

For advanced military applications these concepts integrate naturally into an instrument system such as shown in Fig. 8 (which is quite similar to the new USAF system). The optimum cruise Mach Number and altitude are shown by the command markers on the vertical Mach and altitude scales. The optimum engine setting is shown on the per cent thrust indicator by another command index. The computers providing the range, time, and cruise parameter data will actually be an integral part of the instrument system.

In order to realize the maximum benefit from the computed range data, the range remaining and the range to the selected destination should be indicated comparatively. This can be accomplished by means of a round or linear scale indicator having two pointers or, as shown in Fig. 8, by means of a ground map navigational display where the range remaining takes the form of a circle with a radius equal to the remaining range. The center of this circle is offset from the instantaneous aircraft position by the wind-range* vector. A warning light might also be used to indicate to the pilot when his range remaining is equal to the range back to the nearest base. This would enable the pilot to achieve maximum time in combat, while retaining assurance of his ability to return to base.

Conclusions

Range remaining and time-of-flight for the return leg of a mission can be automatically computed and continuously displayed to the pilot. The accuracy of the range prediction obtained will be comparable to a prediction computed by the pilot using a manual computing aid or the *Flight Handbook*. The accuracy should be better than ±5 to 10 per cent a large percentage of the time. A simplified approximate equation can be mechanized for this purpose requiring the following continuous inputs—total fuel weight, pressure altitude, and ambient air temperature. In addition, the following manual inputs are required—component of wind velocity along flight path, aircraft configuration (optional), fuel reserve (optional), and cruise mode selected (optional).

The principal advantage of automatic range computation for military aircraft is that it will enable a pilot to obtain the maximum possible time in combat from his aircraft. The equipment penalty that must be paid for incorporating this equipment will be slight, especially if the aircraft is already supplied with some type of cruise data storage instrumentation and a navigation display.

* Wind-range = wind velocity × time of flight.

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Aerodynamic Flight Within the Atmosphere *(Continued from page 46)*

for a glider which initiates its gliding phase immediately following the boost phase. The final phase of this type of vehicle is a landing phase. It is possible with proper design for the same vehicle to accomplish both flight profiles. Range is accomplished primarily in the orbiting phase in the former case, while, in the hypersonic glider mission profile, range is accomplished by trade-off of the tremendous kinetic and potential energy imparted to the glider stage during boost. Thus, in the case of a vehicle designed specifically as an orbitor, attainment of maximum range during gliding re-entry is not a prime design requirement allowing re-entry glide to be accomplished with a lift coefficient higher than the optimum for maximum range.

Fig. 7B shows that the glider wing loading does not change during the boost-phase, although, of course, a tremendous change in overall system weight occurs as the fuel is expended in the boosters. In the orbiting case, no coolant is expended during the orbiting phase but a relatively small weight of coolant is assumed to be expended during the gliding re-entry. The hypersonic gliding mission profile, on the other hand, shows that coolant is being expended during a large part of the glide phase.

In the analysis it has been assumed that no landing engine has been employed, thus the landing wing loading is assumed to be the same as at the initiation of the landing phase. Thus an aerospace vehicle will follow a constant wing loading line on a plot of altitude vs. speed in which the actual trace will depend upon the lift coefficients utilized during its glide through the atmosphere.

The Brequet range equation for aerospace vehicles for the glide phase of flight up to, but not including, circular speed may be expressed as follows:

$$R = (H_r/2)\,[(L/D)_A]\,\ln\,[1 - (Vi/H_r g)]^{-1} \quad (11)$$

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(This article will be concluded in the September issue. Part II will discuss the limitations of aerodynamic flight within the atmosphere.)

"Secondary power is all the electric, hydraulic, and pneumatic power required to operate all the many subsystems. . . ."

Secondary Power in Advanced Flight Vehicles

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THE PURPOSE of this treatise is to stress the importance of secondary power in any future national program directed toward new aeronautical frontiers—that is, military vehicles operating up to the fringes of the atmosphere and national exploratory missions beyond the atmosphere from which may evolve future military vehicles. It may be stressed, however, that, although none of the systems or missions mentioned are necessarily Air Force projects, the Air Force in its present program, as well as in its planned future program, will—upon request—assist with all its scientific and technical support available any agency or agencies responsible for these advanced vehicles.

Before discussing the analysis of secondary power systems in advanced vehicles, a definition of secondary power is in order.

Secondary power is all that power aboard a weapon system other than propulsion power—that is, secondary power is all the electric, hydraulic, and pneumatic power required to operate all the many subsystems—communications, navigation, attitude and flight (or trajectory) control, fire control, and life support systems.

Types of Vehicle

To analyze secondary power systems for future national, military, or scientific exploratory systems, it was deemed advisable to break that general topic down into type categories or principal requirements groups (see Table 1).

The first two are advanced conventional or sustained flight vehicles. These vehicles, having primary (propulsion) power for the duration of the mission from which to extract the required secondary power, derive most of their lift from aerodynamic means and are limited to a maximum flight altitude of 150,000 ft. The Mach 3, 80,000-ft. vehicle illustrates this approach. This vehicle would have very elevated temperature problems, and a nuclear-propelled aircraft would have a severe problem of nuclear radiation. These would require extremely large quantities of secondary power for cooling.

The remaining five illustrate the unconventional approach—that is, primary power will, in most cases, last for only a short while, and secondary power will be required long after the shutdown of the primary power plant.

Boost glide vehicles will be powered during the first few seconds or minutes only, rising above the lower atmosphere, soaring, and, upon re-entry, reaching their destination in a hypersonic glide and landing using aerodynamic surfaces. The boost power could be chemical or nuclear, and, during glide, the secondary power could be chemical also or nuclear. These vehicles, which will operate from 100,000 ft. and 4,000 m.p.h. to 300,000 ft. and 18,000 m.p.h., will encounter extremely high temperatures and will require high reliability for moderate durations.

Ballistic missiles, also powered during the first few seconds or minutes only, rise above the lower atmosphere and follow a ballistic trajectory to the target with no aerodynamic lift. The range of operation is between 75,000 ft. at 11,000 m.p.h. and 450,000 ft. at 10,000 m.p.h. The problem with missiles, whether ballistic or guided, is the requirement for extreme reliability. Other problems are high temperature for short duration and possible nuclear radiation from either a primary or a secondary power system, or both.

Satellite vehicles in orbit from 350,000 ft. at 20,000 m.p.h. and up are unpowered but require secondary power which might come from a nuclear source. Boost problems are the same as ballistic missiles. Orbit problems are those of extreme reliability but for long

Table 1. Principal Requirements Groups

(1) Mach 3, 80,000-ft. chemically propelled aircraft
(2) Nuclear-propelled aircraft
(3) Boost glide vehicles
(4) Missiles
(5) Satellites
(6) Lunar vehicles and lunar stations
(7) Interplanetary vehicles

This paper was presented before the IAS Detroit Section, October 14, 1958.

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duration. Interplanetary vehicles and lunar stations will require even longer duration and increase the magnitude of problems associated with satellites.[1]

Looking at installed total secondary power (horsepower) as a sum of the output of secondary generators and pumps (including electric, hydraulic, pneumatic, and environmental control systems), the relationship appears, at least in the past, to have been as follows: HP. $= KWV^2$, where K is a constant of proportionality, W is gross weight of air vehicle in pounds, and V is indicated air speed in knots.[2]

This relationship has shown amazing correlation for all air-breathing aerodynamic vehicles from past to present, including cargo, fighter, bomber, and pilotless missiles. This relationship may or may not hold for the future. Although we hope it will not hold, it seems to be a starting point for the first approximation of required secondary power for future air vehicles. It just cannot hold for nonair-breathing vehicles! If it should hold, a boost glide vehicle at 18,000 m.p.h. of the same weight as the B-52 would require about 900 times the secondary power as the B-52. Of course, it is proposed to be much lighter than the B-52 and so by the formula would require only 16 times the power as the B-52. This is still well beyond the present state of the art.

Total Secondary Power Required

Since many accessory tasks can utilize different kinds of secondary power and various manufacturers will choose all the various kinds, any attempt to predict the amount of any one kind will result in only the roughest estimation. Comparison of various estimates by electrical, hydraulic, or pneumatic engineers can result in great confusion.

Table 2. Advanced Vehicle Power Requirements

Mission Profile	Electrical Kilowatts
Earth satellites	1–50
Unmanned planetary probes	10–500
Manned reconnaissance vehicles (no landings)	500–5,000
Manned expeditions	5,000–30,000

To make a fairly realistic estimate of total secondary power required, it will be necessary to equate a total quantity of horsepower with a particular type of air vehicle, a definite mission of flight profile, and, probably, a time (year). However, such a table leads to detailed material beyond the scope of this paper. Very general brackets for advanced vehicles are as shown in Table 2.

It is no secret that to cut the trip of an interplanetary spaceship from the earth to Mars from 2 years and 239 days to about 90 days requires continual acceleration rather than just a coasting flight along a minimum energy path. A continuous acceleration of only 1/4 in. per sec. from an ion propulsion engine would do the job. Of course, propulsion is really primary rather than secondary power. However, the ion engine for this application needs electric power. Though the amounts of electric power are controversial, one source estimates that to accelerate a 10-ton vehicle from a closed orbit around the earth to Mars calls for a propulsion power of 1,500 kw. at 750 volts and 2,000 amps. If we can attain an overall 25 per cent efficiency, our power plant must have 6,000 kw. capacity. And, for this application, present rotating d.c. machinery, even at 50 per cent overall efficiency, would weigh more than the entire 10 tons allocated for this vehicle.[3]

For electric power, the qualitative requirements should be very little different from the electric power today. However, it is generally agreed that it is quite probable that the tolerances will be narrower (Table 3).[2]

The requirement will exist for this precise power to be supplied by one central source with the entire system capacity, at least 20 kva. by 1965, instead of being converted by small-capacity inverters or within the utilization equipment as is done presently. This integrated power package, in addition to supplying the a.c. power mentioned previously, will be required to furnish all the d.c. power at the various levels as dictated by transistors and other electronic gear. In a study of the requirements on an electric system for Air Force weapons systems to be operational in 10 to 15 years, a total environment was determined (Table 4). This environment is very severe in that it takes the most severe condition of all of the vehicles studied. In other words, some of the criteria are less extreme for certain of the vehicular considerations. It is recommended that all materials, components, and other hardware be tested to these total environment extremes and not be considered acceptable unless they withstand all the extremes. An exception might exist. If a particular item is required for a specific application which will not impose a particular criterion in its extreme, this criterion may be downgraded from its extreme to a more realistic

Table 3. Characteristics of A.C. Power (Probably 3-Phase, 400 cps—Nominal)

Frequency	±1/8%
Voltage	±1/2%
Deviation from a pure sine wave (distortion)	±1/2%
Voltage surge	±10% with recovery to rated value within 1/2 sec.
Phase voltage difference	1% maximum

level, provided this downgrading will avoid undue penalty. (Again, environments identified with specific vehicles entail detailed information beyond the scope of this paper.)

Since some environments are algebraically additive, whereas some are interactive (that is, producing either more or less damage than pure addition of the individual damage), many of these environmental criteria tests must be applied concurrently. For proper combinations of the various criteria to various materials, reference is made to a document listing the combined tests that should be used.[4] Reference is also made to another document listing in greater detail the environments to be simulated, how they should be simulated, and the facility requirements and costs involved in this simulation.[1]

Secondary Power Sources

Now, having talked somewhat about types of vehicle, total secondary power required, quality of electrical power and environment of the electric system, it is time to return to the primary point.

Let's take a trip! We will blast off in the hypothetical advanced vehicle, and here is our mission profile. We launch vertically with rocket boosters which drop off leaving us in our orbit at 18,000 m.p.h. at 250 miles altitude. Now we are soaring with no propulsion power. There is, therefore, no turning shaft or engine pad from which to extract our secondary power. Where do we get it? The power must last for the 7 days we are in orbit, through the firing of the retrorockets, the spiraling in, and the re-entry and landing.

Possible sources include atomic batteries, chemical batteries, solar cells, thermionic converters, thermopile generators, fuel cells, atomic power units (both isotope and reactor), and magnetohydrodynamics. (Atomic batteries, delivering only microwatts or possible milliwatts, are not given consideration in this paper.)

Chemical batteries are, of course, in use today—nickel cadmium batteries in ballistic missiles, silver zinc oxide batteries in aerodynamic missiles, and mercury batteries in satellites. Such batteries (about 15 watt-hours per pound for Ni-Cad, 30 w.-hr./lb. for SilverCad, and 60 w.-hr./lb. for silver zinc) are good for short-duration missions but are too heavy to supply all the necessary power for a long-duration mission. Based on a 50-w.-hr./lb. battery of the same weight and same power output of a solar generator (independent of power level), the battery will last about 60 hours. Therefore, for missions in excess of 60 hours, a photovoltaic generator is better from a weight standpoint.

Solar energy available at the earth's surface, regardless of conversion method used, is 1,400 watts per sq. meter. At present efficiencies of silicon junction photocells, the maximum electric power per square meter irradiated by direct sunlight beyond the earth's atmosphere is 150 watts. A sheet of aluminum of 8 sq.ft., covered with solar cells connected in such a way that

Table 4. Quantitative Definition of Hyperenvironments for Electrical Systems

Environments	Values
Conventional	Existing documents (MIL-E-5272 and MIL-E-4970)
Ozone	11 parts/million at 13 to 21 miles
High-temperature, aerodynamic	0 to 47 miles, 125° to 932°F.
Short-term re-entry environment	60*g* deceleration and 932°F.
Long-term re-entry environment	8*g* and 932°F.
High-vacuum	Approximately 0 pressure and 0 density
High-temperature	5 min. to go from −68° to 932°F.; held at 932°F. for 10 min.; reduce to 752°F., hold for 1 hour; reduce to 702°F., hold 4 hours
Solar radiation	1 to 100,000°A. (max. intensity at 4,500–5,000°A.) as radiated by a "black body" of 6,000–65,000°K.
Mechanical vibration	5 to 55 cps at 3/8 in. double amplitude
Acoustical vibration	190 db., 30 to 10,000 cps
Shock	50 to 200*g* for 11 ±1 m.s.
Acceleration	8*g* for 1 min. to 60*g*
Zero gravity	0*g*
Explosive atmospheres	High-energy fuels and fluids
Ionized gases	Number of electrons 1.5×10^4/cm.^{3} at 38 min. to 1.5×10^8/cm.^{3} at 159 min.
Disassociated gases	Atomic oxygen particles 1×10^{12}/cm.^{3} at cm.^{3} 56.5 miles to 5×10^{12} /cm.^{3} at 75.5 miles Range 50 to 100 per cent atomic Atomic nitrogen particles 1.4×10^{12}/cm.^{3} at 56.5 miles to 1.2×10^8/cm.^{3} at 113.5 miles
Auroras	56.5 to 285 miles, 10^8 electrons/cm.^{2}/sec. at 100,000 every 285 to 565 min., 10 to 100 kev X-rays with intensities of 1,000–100,000 photons/cm.^{2}/sec.
Solid particles	0.2 microns to 8 cm. particles
Magnetic field	2.5 Mev protons above 250,000 ft. to 500,000 ft. (10^8 protons/cm.^{2}/sec.)
Explosive decompression	8,000 ft. to vacuum instantaneously (10.2 psi) 932° to 1.9×10 (12 psi)
Temperature shock	−65° to 932°F. in approx. 2 min.
Pressure shock	S.L. to vacuum in 3 to 5 min.
Nuclear radiation	Dose rate integrated
Neutron	2×10^{14} neutrons/cm.^{2}/sec. 7.5×10^{17}/neutrons/cm.^{2}
Gamma	4.5×10^9 roentgen/hour 2×10^{11} roentgen

the device delivers about 60 volts in direct sunlight at an equilibrium temperature of 50°C., will deliver 100 watts. This generator must be oriented toward the sun by a sun-seeking device. This generator would weigh about 120 lbs., and the entire system (including batteries to supply power during "dark side" operation) would weigh about 260 lbs. Problems with this device include (1) unfolding, in umbrella fashion, the collector after the vehicle is in orbit and (2) temperature, because such cells suffer from decreased output as the temperature is raised.

The thermionic converter, a device which resembles a parallel plate diode, can be designed to operate on chemical, solar, or nuclear heat. Heat boils off electrons from a high-work function material cathode, and these electrons are collected by a low-work function material anode. The voltage obtained is about equal to the difference between work functions, and practical efficiencies are about 8 per cent overall—with 30 per cent being theoretically possible. The current limiting space charge which tends to form between the plates may be reduced by the introduction of a cesium atmosphere or by close electrode spacing in a vacuum. Maintaining extremely close spacing, less than 1 mil, of large plates when the cathode temperature is 2,500°C. and the anode is 700°C. or more is a very difficult problem.

Thermopile generators may also obtain heat from chemical, solar, or nuclear sources. The very low efficiencies (less than 1 per cent) have precluded their consideration as a power source until recently when advances in the art of solid-state physics indicate that efficiencies up to 15 per cent should be attainable through the use of semiconductor materials.

To supply 100 watts, a thermocouple generator—with cooler, sun-seeking system and batteries for "dark side" operation—would weigh about 360 lbs. (100 lbs. heavier than the photovoltaic system of the same power rating). This is based on a temperature difference of 400°C., 0.1 volt per couple, and 5.6 per cent efficiency.

The thermocouple generator with a radioactive heat source for 100 watts would also weigh about 360 lbs.

Nuclear reactors for power in the range of 50 to 100 kw. with shadow shielding indicate about 250 lbs./kw. With limited shadow shielding, a 100-kw. unit might be reduced to 10 tons total weight.

Fuel cells, although described in the literature since 1785, are still in their infancy. The fuel cell or continuous-feed battery will convert chemical energy directly into electrical energy as long as fuel is supplied. The most common approach at present is the Hydrox cell in which pure hydrogen and oxygen are stored and fed into the reaction chamber where, by "cold combustion," they combine chemically to produce water and release electricity to an external circuit.

The hydrogen and oxygen may be stored as gases at 6,000 psi. This approach presently results in about 65 w.-hr./lb., depending upon operating time. A better approach stores gaseous hydrogen at 6,000 psi inside a tank of liquid oxygen at 600 psi (both at 150°K.). This approach should produce approximately 110 w.-hr./lb. The best approach appears to be with liquid storage of both hydrogen and oxygen with an output of 105 to 815 w.-hr./lb., depending upon duration of mission and year of mission (and current state of the art). This method of storage introduces severe cryogenic problems in that hydrogen must be stored at below −400°F. and at that temperature its critical pressure is only 188.2 psi—too low for use in the high-pressure cell without compression or superheating.

The Redox (reduction-oxidation) cell offers great advantages over the Hydrox cell in that it eliminates gaseous electrodes and can use cheap, crude fuels, such as kerosene or alcohol. This cell promises from about 266 up to 860 w.-hr./lb. For the special case where atmospheric "air" will always be available, such a chemically regenerated cell promises up to 3,200 w.-hr./hr.

All the above-mentioned fuel cells are limited in that they must carry all the necessary fuel for the entire mission and are, therefore, very heavy for long missions. The device which offers the greatest promise is the fuel cell which does not need to carry much fuel but will still operate for long periods. Such a cell is the solar (or nuclear) regenerative fuel cell which would store only small quantities of hydrogen and oxygen, possibly in either the gaseous or liquid forms. The water formed in the cell from the electricity-producing reaction is fed into a reaction chamber where it is dissociated into hydrogen and oxygen to complete the cycle. It is estimated that the solar regenerative reactor could handle fuel for 10 watts/lb. Coupled with a generator producing 144 watts/lb. (or even 3,200), the reactor is the significant weight and the output would be essentially 10 watts/lb. This means that a 15-kw. generator would weigh about 1,600 lbs., irrespective of operating time. Therefore, for one year's operation, this cell would weigh about 6/1,000th as much as a Hydrox cell (computed at 600 w.-hr./lb.). The thermal or nuclear regenerative fuel cell is, however, in early stages of research, and feasibility has not been proved.

Problems associated with fuel cells are many. Obvious ones are the control of the rates of flow of both hydrogen and oxygen in the proper ratio to meet the required load, decomposition of the catalyzing electrodes in the electrolyte, fuel storage, and system weight reduction.

Magnetohydrodynamics, in an early phase of research and development and covering a wide field of work, is of interest here because of the probability of generating an electric potential by passing a conducting fluid, a gas such as mercury at 2,000°K., through a magnetic field. This principle seems to offer a specific power in the range of 100 to 1,000 kw./lb.

Conclusions

Secondary power will merit increasing importance with time and the development of advanced unconventional vehicles. This paper has attempted to present

(*Continued on page 63*)

"It may be concluded that the best all-round type of rotating-output engine for airborne applications is the free-turbine type with variable compressor stators."

Why Free Turbines?

D. P. Edkins

General Electric Company

Mr. Edkins, Supervisor, Aircraft Systems Analysis, Preliminary Design, at G-E's Small Aircraft Engine Department, Lynn, Mass., since joining the Company in 1955 is intimately familiar with aircraft power-plant requirements. After receiving his B.A. from Cambridge University in 1936, Mr. Edkins joined Westland Aircraft Ltd. and was appointed assistant chief designer. In 1948 he became Supervisor, Preliminary Design, for Canadair in Montreal and in 1951 assumed a similar position with Chance Vought Aircraft in Dallas, Tex. Mr. Edkins received an M.A. degree from Cambridge University in 1940 and is a member of the Society of Automotive Engineers and an associate fellow of the Royal Aeronautical Society.

SINCE THE early days of gas turbines producing shaft power, there have been examples of all three basic types—solid-spool, twin-spool, and free turbine (Fig. 1). Thus the General Electric TG100, a very early turboprop engine which flew in 1945, was a solid-spool type; the Rolls-Royce Clyde which flew in 1948 was of the twin-spool variety; and the Bristol Theseus, which flew and was model-tested shortly after the TG100, was a free-turbine engine (Fig. 2). Historically, it is to be expected that examples of all the feasible configurations would quickly appear on the early scene, regardless of their respective merits, merely from the fact that they were feasible. This pattern is discernible in many new fields of endeavor. Thus monoplanes were appearing along with biplanes and multiplanes in the early days of flight, long before their final ascendancy was established. However, the technology of gas turbines has now advanced to a sufficient extent that a reasoned choice can and should be made between the three basic types for any particular field of application. First, however, let us consider the consuming devices which the gas turbine will drive. These are the helicopter rotor and the propeller. A brief summary of their characteristics as they affect the engine will be given.

Helicopter Rotor

This is a somewhat peculiar device in that it provides vertical lift at zero flight speed and also forward thrust at normal flight speed. In the latter condition, we have the well-known problem of retreating blade stall[1] which militates toward a high rotor rotational speed. At such higher rotor speeds, the power required at maximum forward speed will still be within that available from the engine sized for hover conditions, particularly if the hover includes hot-day capability. For helicopters with low or moderate disc loadings, such as would be dictated by acceptable autorotative descent rates or by rotor weight and size optimization, it turns out that the maximum rotor speed is set by the forward flight condition

Symbols

- w = compressor mass flow
- θ = temperature ratio T_2/T_0, where T_2 = compressor inlet temperature and T_0 = ambient temperature
- δ = pressure ratio P_2/P_0, where P_2 = pressure at compressor inlet and P_0 = ambient pressure
- N = compressor or turbine physical speed
- T_4 = first-stage turbine inlet temperature
- h = enthalpy per pound of air
- T_t = power turbine inlet temperature

and that optimum rotor hover thrust is developed with a lower rotor speed, as depicted in Fig. 3. Of course, it has not been possible to make use of this increased rotor thrust at reduced r.p.m. with piston engines because the r.p.m. cannot be reduced without reducing power also; a two-speed gear would be necessary. Fig. 3 shows in concise form the relationship of power and r.p.m. needed in a rotor, and an engine which matches these characteristics will, other factors being equal, be the best. For higher disc loadings, such as might be used in a multiengine helicopter not requiring autorotative capability, the best rotor speed for hover efficiency can approximate, and eventually exceed, the speed optimized with respect to forward flight. Under these conditions, no advantage accrues from the ability to reduce rotor speed for hover. However, another possibility for improved performance arises—a higher rotor speed for hovering than for forward flight is advantageous for high disc loadings. The tip Mach Number of the rotor during hovering can be higher than can be tolerated during forward flight. Thus an engine which can provide

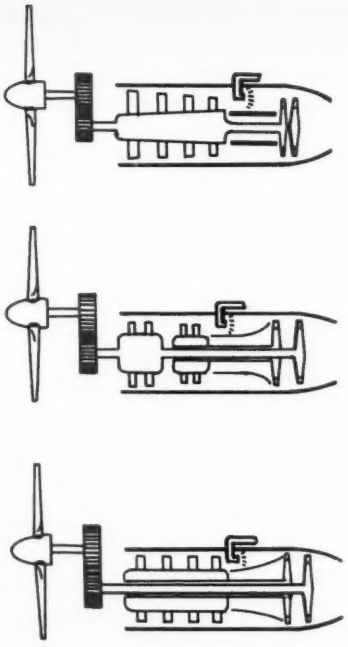

Fig. 1.

variable rotor speed independently of power is again desirable for a helicopter of high disc loading. Current disc loadings, particularly on twin-rotor helicopters, are within the range where greater lift can be obtained with the rotor speed reduced for hovering.

Propeller

The propeller may be looked upon as an assembly of rotating airfoils. All airfoils have a fixed relation between lift/drag ratio and lift coefficient. For maximum efficiency it is clear that operation in the vicinity of the maximum L/D, and therefore of the corresponding lift coefficient, should be sought. This means that, as power input to the propeller is reduced, the forward speed or the r.p.m., or both, should be reduced. Fig. 4 shows how propeller efficiency can be maintained at a high level by suitable choice of the r.p.m. for each power level.

An additional factor which could require the r.p.m. to be reduced, under cruising conditions, is that of propeller noise. If the helical tip Mach Number of the propeller is taken as the criterion for assessing the noise level of a propeller,[2] it is clear that a reduction of r.p.m. is the only degree of freedom available, for a given propeller at a given forward speed, for staying within some limiting tip Mach Number (as shown in Fig. 5).

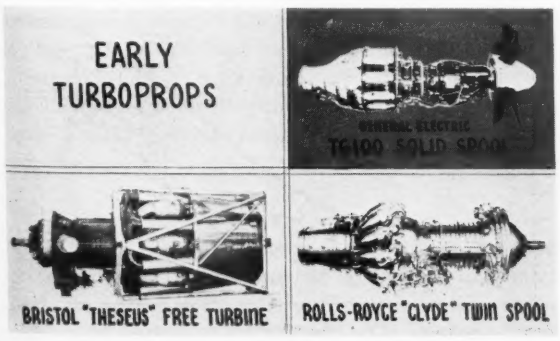

Fig. 2.

Engine Considerations Common to Solid-Spool, Twin-Spool, and Free-Turbine Turboprops

The building blocks which are of interest in examining the three types of engine are the compressor and the turbine. Typical performance maps for these components are shown in Figs. 6 and 7. These are of interest in studying the behavior of the three types of engine at part-power, which is where the difference in engine arrangement shows up.

On the compressor map, operation of the engine at maximum power is represented by point A. To reduce power, the compressor speed can be reduced along a line such as AB, where the stall margin, represented by the

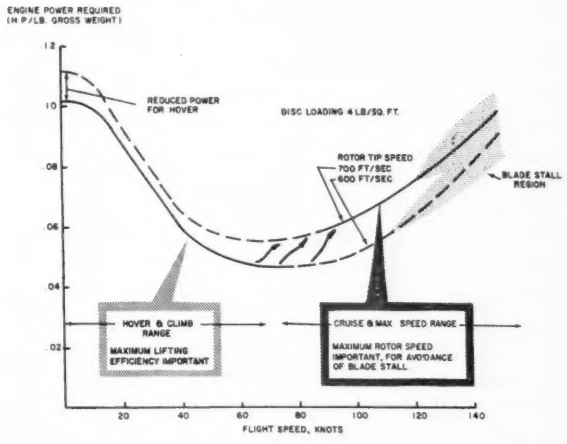

Fig. 3. Helicopter power as influenced by rotor speed.

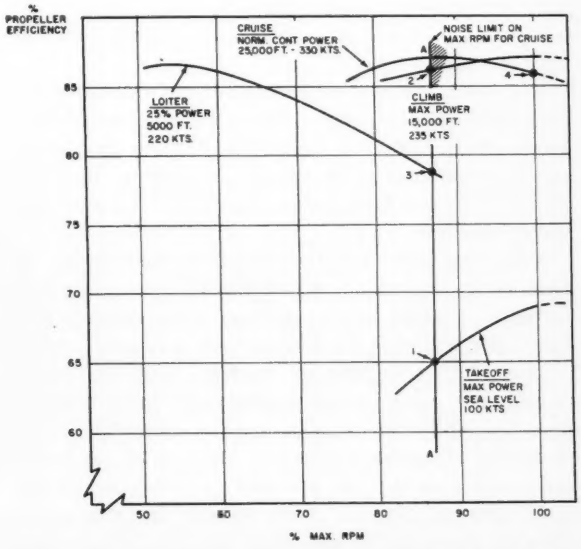

Fig. 4. Propeller efficiency at important representative flight conditions.

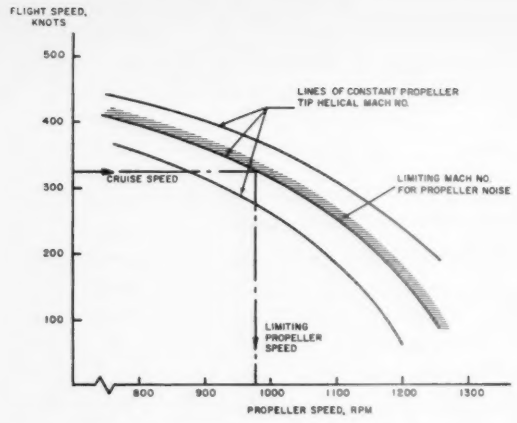

Fig. 5. **Relation between flight speed and propeller speed as influenced by noise level.**

distance between the operating line AB and the stall line, remains sensibly constant. The incentive for operating along AB is seen by noting that the loci of high compressor efficiency contours are more or less along this line. However, a price has to be paid for this—which manifests itself when greater power is needed—i.e., the engine has to be accelerated to get back toward A. Obtaining the necessary accelerating torque involves eating into the stall margin, and it is clear that problems of acceleration time, stall protection by the control system, and inertia of the rotating parts are entailed.

There is an alternative way of reducing power in which the compressor speed is not reduced and the operating line is along a constant-speed line AC. The problem of accelerating the engine is thus sidestepped, but the price in this case is easily seen from the map to be a fairly rapid departure into regions of low compressor efficiency. A second, not so obvious, price also has to be paid—along AC, the airflow remains substantially constant, and, to reduce engine power by a given amount, it is necessary to reduce the turbine temperature by a greater amount than with reduced airflow (as along AB). This lower temperature is thermodynamically less efficient.

The case of the low-pressure spool of a twin-spool engine when operating a propeller is a special one.[3] It is represented by line CT, where C is the maximum power point and reduced power involves moving toward stall, albeit at increased compressor efficiency. So much for the compressor.

Figs. 7(a) and 7(b) show typical turbine maps. A twin-spool arrangement which also incorporates a free turbine is possible but is ruled out as too complex mechanically and from the point of view of control.

In order to understand turbine operation more clearly, the gas generator turbine and power turbine have been shown on separate maps. An additional restraint is, of course, imposed in the case of the solid-spool engine, in that the physical speed N must be the same for both portions of the turbine, and this speed must be the same as the N of the compressor—and also, incidentally, as that of the output shaft. The twin-spool turbine operation will lie somewhere intermediate between the operation of the solid-spool and the free turbine.

In order to reduce the power output of the engine, the turbine inlet temperature T_4 has to be reduced. Referring to Fig. 7(a), it turns out that the two parameters plotted, $\Delta h/T_4$ and $N/\sqrt{T_4}$, do not change much when T_4 is reduced.

However, the direction which reduced-power operation takes can be AB or AC, which correspond to the similarly labeled lines of Fig. 6. AB is along the normal operating line, while AC results if we choose to operate at constant physical speed. It is seen that AC is undesirable on two counts—compressor and turbine efficiency loss. AB, on the other hand, is in the general direction of minimum deterioration of component efficiency on Fig. 6 and of low deterioration on Fig. 7. The physical speed drops typically to 85 per cent of its maximum along AB for full modulation of power in the flight range.

In Fig. 7(b) we have several important considerations:

(1) Operation of a free power turbine is under no restraint as to physical speed so that the best corrected speed can be achieved for each power level. This would be ideal operation at point A_1, or constant corrected speed $N/\sqrt{T}$. However, this is not possible, so the best operating line will be one which results in least deterioration of turbine efficiency—that is, along A_1B_1. The physical speed for full power modulation falls by a greater amount than the corrected speed along this line—typically to 60 per cent of its maximum, much more than could be tolerated if the turbine were under the restraint of operating at the same speed as all or part of the compressor. It turns out that operation along A_1B_1 is very close to the r.p.m.-power relationship best for a propeller, as will be discussed later.

(2) The second mode of operation would be where the restraint imposed by operation along AC in Figs. 6 and 7(b) is applied to the power turbine—i.e., a solid-spool engine. This results in operation along A_1C_1 with resultant loss in efficiency from the fact that A_1C_1 is in the general direction of the maximum deterioration of turbine efficiency.

The low-pressure turbine of the twin-spool engine operates within the region bounded by A_1B_1 and A_1C_1.

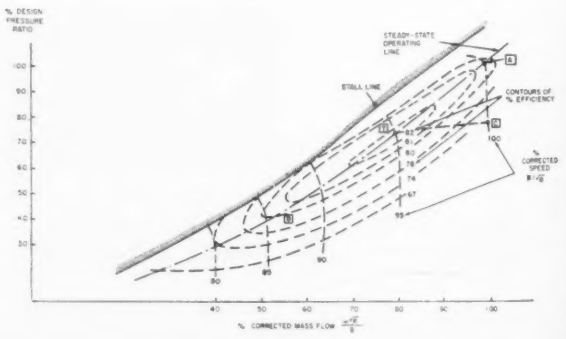

Fig. 6. **Typical compressor map.**

(3) The third mode of operation is also along A_1C_1 but arises from a different cause from that of the previous mode. It occurs in any of the types of engine where the power-consuming device requires constant physical speed operation, such as in a helicopter rotor.

The significance of points D_1 and E will be explained later.

Summarizing the implications of Figs. 6, 7(a), and 7(b), it is seen that compressor and gas generator turbine operation can be within the limits of the lines AB and AC and that the former is preferable from the efficiency point of view. The power turbine can operate between A_1B_1 and A_1C_1, and the former is again preferable. If we have to operate a solid-spool engine along AC, A_1C_1, relative penalties are experienced in component and thermodynamic efficiency. Where a free-turbine engine has to be operated along AB, A_1C_1, only a single penalty is incurred—i.e., on the power turbine efficiency—so that there is an overall improvement over solid- and twin-spool engines. Finally, the low-pressure spool of a twin-spool turboprop has a compressor operating line CT involving some penalty in full power efficiency.

Operation of a solid-spool engine along AB is unacceptable for a helicopter rotor and presents acceleration stall margin problems in a turboprop engine which are more severe than those of a free-turbine engine with AB-type operation, or of a twin-spool engine.

The ability in the free-turbine engine to select the best gas-generator speed and, additionally, to use the best power turbine speed in a turboprop results in improved s.f.c. characteristics at part-power. Fig. 8 illustrates how the deterioration of s.f.c. resulting from the reduced cycle temperature at part-power, common to any straight cycle turboprop, is also accentuated in the solid-spool engine by the lower efficiencies necessarily incurred.

We will now examine the maps of Figs. 6 and 7 in relation to the helicopter rotor and propeller.

Helicopter Rotor

Solid-Spool

Remembering that the helicopter rotor would like to run at a constant speed, except possibly for a slight reduction in r.p.m. at full power hover, it is seen that both compressor and turbine have to be operated along the lines labeled AC in Figs. 6 and 7, with resultant deterioration in efficiency. Remembering also, from Fig. 3, that cruising involves quite low power levels of 50% or less, we see that the solid-spool engine is not well suited for driving a helicopter rotor, from the standpoint of obtaining the optimum engine component efficiency. Figs. 9 and 10 show the compressor and turbine operation in pictorial summary form.

Twin-Spool

The rotor is here connected to one half of the compressor and to the low-pressure turbine so that these parts are sujbect to the same operating conditions as the solid-spool engine just discussed. The degree of freedom of operation between the two halves of the com-

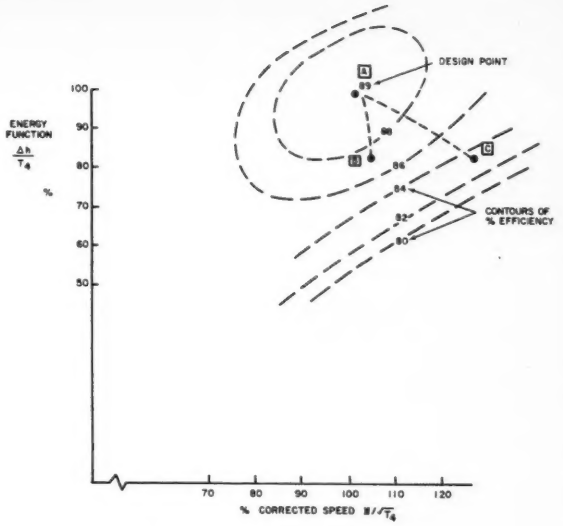

Fig. 7(a). Gas generator turbine map.

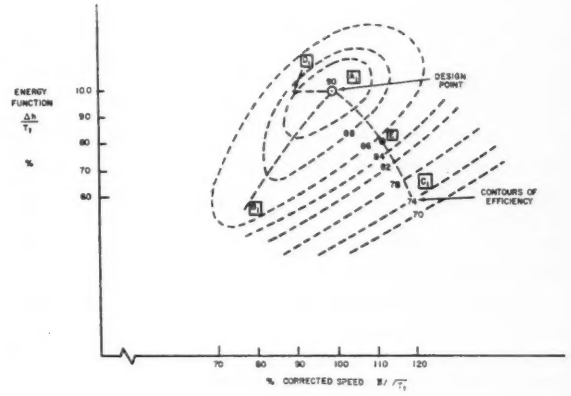

Fig. 7(b). Power turbine map

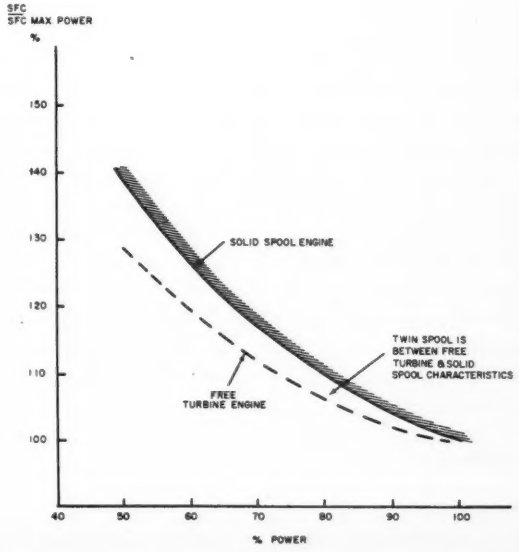
SFC / SFC MAX POWER %
SOLID SPOOL ENGINE
TWIN SPOOL IS BETWEEN FREE TURBINE & SOLID SPOOL CHARACTERISTICS
FREE TURBINE ENGINE
% POWER

Fig. 8.

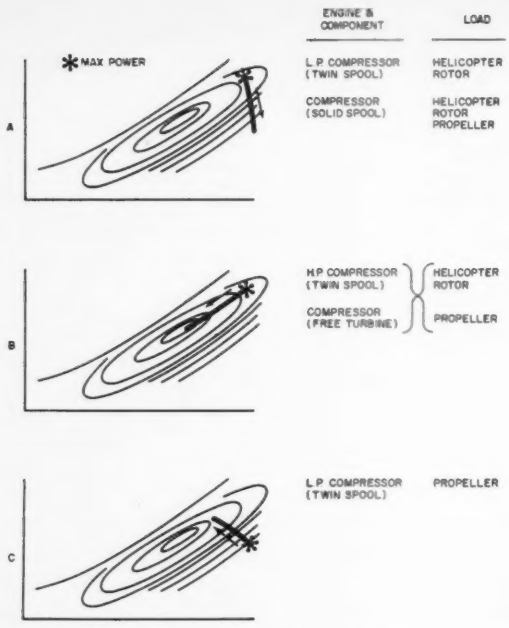

Fig. 9. **Compressor map-load relations.**

pressor is restricted by matching requirements, but the high-pressure compressor and turbine can be run at a reduced r.p.m. when at part-power and thereby allow of a slightly higher efficiency relative to the solid-spool engine. The pictorial summary is seen in Figs. 9A, 9B, and 10A.

Free Turbine

Here the rotor can be operated at a slightly reduced r.p.m. for hover while the gas generator portion of the engine is operating at full r.p.m. and power, with only a minor loss in power turbine efficiency compared with full rotor r.p.m.—of the order of 1.5 per cent. The operating line of the power turbine under this condition is A_1D_1 of Fig. 7(b). Under cruising conditions the rotor can be operated at reduced power at maximum r.p.m., with again only minor departure from peak turbine efficiency, as shown in Fig. 7(b) where point E represents the maximum migration of the operating point along the constant physical speed line A_1C_1. The gas generator can be reduced in power and r.p.m. simultaneously so as to maintain good compressor and turbine efficiency. This, it will be remembered, involves possible difficulty in accelerating. However, the inertia of the rotating parts is relatively small. If the compressor is a high-pressure one and, therefore, more susceptible to stall, the acceleration problem can be overcome, for example, by using variable stators, as on the General Electric T58 and T64 helicopter engines. Figs. 9B and 10A summarize the above.

Propeller

Solid-Spool

Fig. 11 shows two typical examples of the breakdown of power level versus time of engine operation. Fig. 4 demonstrated that, for maximum efficiency, the propeller should be operated over a wide range of rotational speeds. Figs. 11 and 4 together clearly demonstrate the difficulty which has to be faced in trying to optimize the propeller-engine combination over the whole range of flight conditions. The difficulty lies in the choice of propeller speed and therefore—in this case—engine speed when this is restricted either to a narrow range or to a fixed speed by engine operating and efficiency limitations. The restraint imposed by noise, as shown in Fig. 5, also has to be taken into account. The result of these considerations might typically be a propeller speed choice such as the line AA of Fig. 4. Here the cruising efficiency is a maximum, but the take-off, climb, and loiter efficiencies are lower than their respective maxima and are represented by points 1, 2, and 3. Figs. 9A and 10B summarize the component map situation.

Twin-Spool

The situation just described is alleviated somewhat in a twin-spool engine. The operation of the compressors and turbines resembles that of the solid-spool engine inasmuch as the two halves of the compressor have to be matched as to airflow. However, it also resembles the free turbine to the extent that the power turbine speed can be allowed to vary despite its mechanical connection to the low-pressure compressor spool. This variation is typically about 15 per cent, and Fig. 4 shows that this allows good propeller efficiency to be achieved at, say, take-off, climb, and cruise. However, a drop in efficiency will still be experienced under low-power conditions, such as for loitering or holding flight patterns. An additional problem presents itself when it is required to run the propeller at high r.p.m. while drawing low

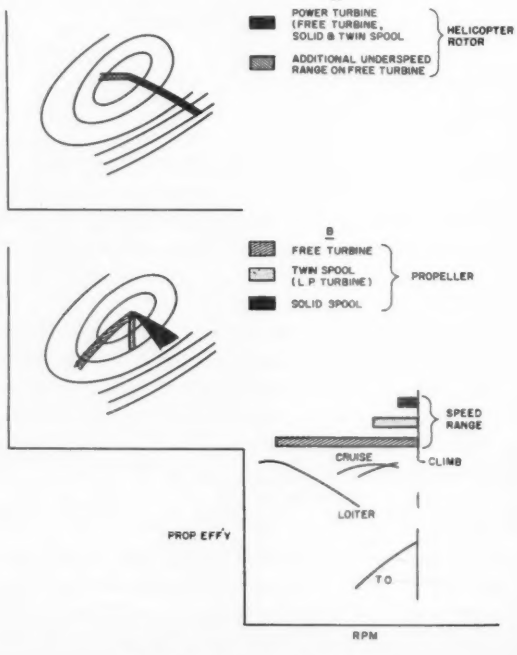

Fig. 10. **Turbine map-load relations.**

power from the engine, such as on the approach to a landing. A high r.p.m. is desirable in case of a wave-off. The low-pressure compressor has to operate at point C in Fig. 6, while the high-pressure section operates at, say, point B. In general, this will produce sufficient mismatch of airflow between the two halves of the compressor that some excess air has to be blown off through bleed valves. Figs. 9C and 10B are the appropriate simplified maps.

Free Turbine

Here the propeller can be provided with the correct blend of rotational speed and power for it to operate over the envelope of peak efficiencies, and the diameter and basic rotational speed set by engine gear ratio can be selected with due regard for the noise considerations indicated by Fig. 5. For example, a diameter and rotational speed can be chosen to provide high thrust for take-off and climb. Such a propeller would be excessively noisy in high-speed cruise at full rotational speed, as well as low in efficiency, because of operation at point 4, Fig. 4. However, the speed can be reduced so as to come within the limitations of Fig. 5 and to reach peak efficiency at the same time. Further, high propeller efficiency can be achieved at the low-power levels necessary for endurance-type flight, and it was shown on Fig. 7(b) that nearly peak turbine efficiency can be maintained at the low-power levels also. Even with the degree of flexibility afforded by the free turbine, some compromise will usually be needed, and has in the past been necessary with piston engines driving propellers. In the example of Fig. 4, this compromise appears as reduction in the take-off thrust below the maximum available at 100 per cent r.p.m. as evidenced by the lack of a peak in the appropriate efficiency curve. Figs. 9B and 10B show the maps.

Conclusions

The free-turbine type of gas turbine has certain inherent advantages when considered in relation to the needs of the helicopter rotor and the aircraft propeller. The attainment of low fuel consumption in the engine requires, among other things, a high-pressure ratio. To achieve high-pressure ratios, the compressor commonly is split into two spools or is provided with variable stator vanes. Since the latter alternative also permits the use of a free-turbine design (if we exclude the possibility of three separate rotating parts as too complex), it may be concluded that the best all-round type of rotating-output engine for airborne applications is the free-turbine type with variable compressor stators.

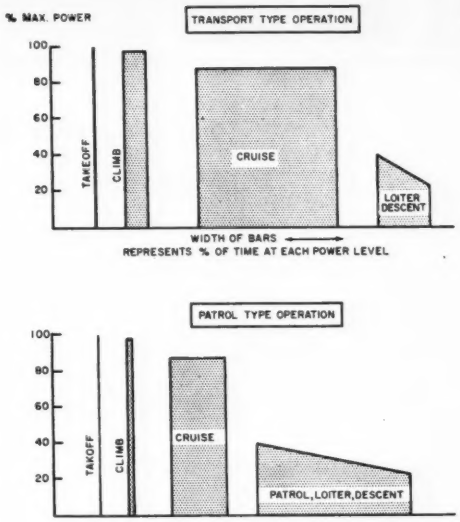

Fig. 11. Percent power-time spectra.

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Secondary Power in Advanced Flight Vehicles (Continued from page 57)

some of the problems and objectives in this field. The problems are many and great; the objectives are far reaching. It behooves all who are working in the field of supplying systems, subsystems, and components for accessory or secondary power systems to concentrate on the attainment of revolutionary, as opposed to evolutionary, advances.

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Letters

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Education and the IAS

■ The separation of education and industry has continuously been marked by the large lag between current engineering practice to accomplish the problem and background material contained in our curriculum. With the present pace of scientific progress and the industrial, economic, ideological race in which this country is engaged, it is mandatory that graduates of our institutions of higher learning, particularly the engineers and scientists, have the best preparation to meet not only the current problems but the challenges of today and tomorrow. To accomplish this, industry and education must expand their mutual exchanges on all aspects of current and future problem areas in the fields of engineering.

The IAS has demonstrated its recognition of the need for this exchange and has held joint meetings with the Aeronautical Division of the American Society for Engineering Education at the Annual Meeting for the past 6 years. In addition to this, two joint meetings were held with the same society in Los Angeles during the last 2 years, and a committee for education has been formed within the IAS.

Aeronautical engineering defies a rigorous definition; this has been true since the inception of the field, and, with the expansion of astronautics and space exploration, the ability even to approximate a definition becomes almost impossible. The basic concept in this field has been the design and construction of a vehicle for transportation and the inherent basic studies underlying this concept. All fields of engineering necessary to accomplish the action have been included in aeronautical—and now astronautical—engineering, with one unifying objective—the end result or product. As such then, the IAS has appeal to all other disciplines operating in this area since it represents the aeronautical sciences, and in the same way the Aeronautical Division of the ASEE has appeal to the other disciplines in engineering education. To further the integration of *education and industry*, the two organizations should continue to be closely allied.

To continue this extremely valuable effort, I would like to suggest that the Education Committee be made a permanent part of the IAS and that the problems of higher education, not just the problems of high schools, be considered. Subcommittees composed of educators and industrialists would be responsible for the various phases in this area such as technical institutes, nonaccredited schools, extension schools, and accredited undergraduate and graduate schools. Many of us feel that a regular report on the activity of the IAS in the education field is necessary to accomplish a closer partnership between education and industry.

It is suggested that a page in A/SE be devoted regularly to presenting and reviewing activity in industry and education.

Maj. V. S. Haneman, Jr., USAF, Assoc. Prof., Aero. Engrg., AF Inst. of Tech.

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Acoustics, Sound, Noise

Effect of Altitude on Output of Sound Sources. T. J. Schultz. *Noise Control*, May, 1959, pp. 17–21, 54. 13 refs. Presentation of several types of sound sources and curves showing the variation with altitude of the acoustical output of these sources. Theoretical justification of this dependence is given.

Vibration and Noise Problems Expected in Manned Space Craft. H. E. Von Gierke. *Noise Control*, May, 1959, pp. 8–16. 16 refs. Review of the information on noise, vibration, and transient accelerations, and evaluation of the extent of problems involved.

Some Measurements of Noise Reduction of Air Base Structures. R. M. Hoover and A. C. Pietrasanta. *USAF WADC TN 58-243 [AD 208156]*, Nov., 1958. 29 pp. Description of the noise reduction measurements and comparison of the results with calculated values. The effect of operable sash windows, open and closed, on the noise reduction is investigated.

Acoustical Factors in Jet Airport Design. Ken Eldred. *ASA J.*, May, 1959, pp. 547–557. 23 refs. Review of the relationship between the noise resulting from commercial jet and propeller airliner operations, including take-off, taxi, and idle, for various projected traffic densities and various airport building functional design criteria. Methods and examples are presented which expedite initial visualization of the major acoustical factors in an airport design situation and enable evaluation of possible wall and roof structures.

A New Facility for Jet Noise Investigation. R. B. Tatge, R. L. Lawrence, and W. F. Venneman. *Noise Control*, May, 1959, pp. 32–36. Description of the operation of a system which provides for measurement of thrust, thrust coefficient, pressure ratio, temperature, and sound.

Experiments with Screens and Grids for Suppressing Jet Engine Noise. H. U. Wisniowski. *Canada, NAE LR 231*, Oct., 1958. 26 pp. Test results from noise suppressors of conventional screen and the grid type. The sound level reductions obtained which could be practically applied amounted to 16½ db. Higher reductions (up to 20 db.) were penalized by the adverse influence of the suppressor on tailpipe temperature and engine thrust.

Noise Survey Under Static Conditions of a Turbine-Driven Transonic Propeller with an Advance Ratio of 4.0. M. C. Kurbjun. *U.S., NASA Memo. 4-18-59L*, May, 1959. 14 pp. Measurement of overall sound-pressure levels and frequency spectra of the noise emitted from a three-blade propeller. The effects of power changes on the noise levels and spectra are also shown.

Calculated and Measured Stresses in Simple Panels Subject to Intense Random Acoustic Loading Including the Near Noise Field of a Turbojet Engine. L. W. Lassiter and R. W. Hess. *U.S., NACA Rep. 1367*, 1958. 10 pp. Supt. of Doc., Wash., $0.20.

Aerodynamics, Fluid Mechanics

Algunos Progresos Importantes en Aerodinámica desde 1946 (The First Daniel and Florence Guggenheim Memorial Lecture). Theodore von Kármán. *(1st Internatl. Congr. Aero. Sci., Madrid, Sept. 8, 1958.) Ing. Aero.*, Nov.-Dec., 1958, pp. 21–32. In Spanish. Historical review of developments in aerodynamic theory; included in the discussion are such topics as wing theory, slender wings and bodies, interference effects, aeroelastic theories, transonic flow, hypersonic flow, boundary-layer theory, and theory of turbulence.

Aerothermochemistry, Dissociation, Ablation

Laminar Heat Transfer Around Blunt Bodies in Dissociated Air. N. H. Kemp, P. H. Rose, and R. W. Detra. *(Avco Res. Lab. RR 15*, May, 1958.) *J. Aero/Space Sci.*, July, 1959, pp. 421–430. 11 refs. USAF-supported research.

Evaporation Into a Boundary Layer. II—Dissociation in Evaporation. Ernest Bauer and Martin Zlotnick. *(Avco Res. & Adv. Devel. Div. RAD TM 58-126*, Nov. 21, 1958.) *Phys. Fluids*, Mar.-Apr., 1959, pp. 236, 237.

Aerothermodynamics

A Study of the Motion and Aerodynamic Heating of Ballistic Missiles Entering the Earth's Atmosphere at High Supersonic Speeds. H. J. Allen and A. J. Eggers, Jr. *U.S., NACA Rep. 1381*, 1958. 16 pp. 16 refs. Supt. of Doc., Wash., $0.25. Presentation of an analysis of the velocity and deceleration history of ballistic missiles entering the atmosphere, the results then being used to determine the means available for minimizing aerodynamic heating.

An "Insulating" Boundary-Layer Experiment. F. H. Durgin. *J. Aero/Space Sci.*, July, 1959, pp. 450, 451. AFOSR-supported description of the experiment and presentation of results.

Boundary Layer

Zamknutyi Konvektivnyi Pogranichnyi Sloi. G. Z. Gershuni and E. M. Zhukhovitskii. *AN SSSR Dokl.*, Jan. 11, 1959, pp. 298–300. In Russian. Derivation of a solution for the problem of closed convective boundary layers in horizontal circular cylinders.

On Heat Transfer to Laminar Boundary Layers. H. A. Hassan. *J. Aero/Space Sci.*, July, 1959, p. 464.

The Growth of a Laminar Boundary Layer on a Flat Plate Set Impulsively Into Motion. L. A. Rozin. *(Prikl. Mat. i Mekh.*, May-June, 1958, pp. 407–412.) *PMM—Appl. Math. & Mech.*, No. 3, 1958, pp. 568–575. Translation.

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Nachprüfung der einfachen Rechenmethode für dreidimensionale laminare Grenzschichten mit Hilfe von exakten Lösungen. J. A. Zaat. *Netherlands, NLL TR F.202*, June, 1957. 24 pp. 13 refs. In German. Application of a simplified approximate method to the calculation of three-dimensional boundary layers and comparison of the results with exact solutions.

Eddy Diffusivities in Forced and Free Convection Boundary Layers. D. E. Bourne. *J. Aero/Space Sci.*, July, 1959, pp. 459, 460. Discussion of the assumption that in incompressible turbulent boundary layers over heated surfaces the eddy momentum diffusivity is identical in value with the eddy heat diffusivity.

Flow of Fluids

Limiting, Self-Similar, One-Dimensional, Non-Steady Motions of a Gas (Cauchy's Problem and the Piston Problem). S. S. Grigorian. *(Prikl. Mat. i Mekh.*, May-June, 1958, pp. 301–310.) *PMM—Appl. Math. & Mech.*, No. 3, 1958, pp. 417–430. Translation.

Cauchy's Problem and the Problem of a Piston for One-Dimensional, Non-Steady Motions of Gas (Automodel Motion). S. S. Grigorian. *(Prikl. Mat. i Mekh.*, Mar.-Apr., 1958, pp. 179–187.) *PMM—Appl. Math. & Mech.*, No. 2, 1958, pp. 244–255. Translation.

Statsionarnoe Dvizhenie Viazkoi Zhidkosti. I. I. Vorovich and V. I. Iudovich. *AN SSSR Dokl.*, Jan. 21, 1959, pp. 542–545. In Russian. Study covering the problem of steady laminar flow of a viscous liquid, with particular emphasis on the differential properties of the solution in closed region and the convergence of Galerkin's method.

Thermal Instability of Viscous Fluids. Chia-Shun Yih. *Quart. Appl. Math.*, Apr., 1959, pp. 25–42. 13 refs. OOR-sponsored analysis presenting the relationship between the variables for neutral stability and the results concerning the effect of rotation on stability.

Die Erweiterung des Zirkulationssatzes von W. Thomson auf zähe (viskose) Flüssigkeiten. Walther Kaufmann. *ZFW*, Apr., 1959, pp. 103–106. In German. Modification of Thomson's circulation theorem to cover the case of a viscous fluid. It is shown that the theorem of circulation conservation with time is generally invalid, but that a change of the circulation with time, or the change of the vortex flux through a vortex tube, occurs.

On a Class of Solutions of Grad's Moment Equations. V. S. Galkin. *(Prikl. Mat. i Mekh.*, May-June, 1958, pp. 386–389.) *PMM—Appl. Math. & Mech.*, No. 3, 1958, pp. 532–536. Translation. Analysis of an ideal monatomic Maxwellian gas in the absence of external forces under the assumption that all the moments of the distribution function are functions of time t, and the macroscopic velocity depends linearly on the coordinates.

On the Eccentric Rotation of a Circular Cylinder in Fluid. Syūsuke Iida. *JSME Bul.*, Feb., 1959, pp. 1–9. Approximate calculation of the fluid motion and comparison with experiments. The hydrodynamical force and the attached moments of inertia are derived.

Second Approximations for the Stress Tensor and the Heat Flux in a Gas. Hsun-Tiao Yang. *Phys. Fluids*, Mar.-Apr., 1959, pp. 237, 238.

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Flow with a Detached Shock Wave About a Symmetrical Profile. O. M. Belotserkovskii. *(Prikl. Mat. i Mekh.*, Mar.-Apr., 1958, pp. 206–219.) *PMM—Appl. Math. & Mech.*, No. 2, 1958, pp. 279–296. 11 refs. Translation. Solution of the detached shock wave problem using integral relations proposed by Dorodnitsin. The problem of integrating a system of nonlinear partial differential equations is reduced to that of numerically solving an approximating system of ordinary differential equations.

Investigation of the Drag of Various Axially Symmetric Nose Shapes of Fineness Ratio 3 for Mach Numbers from 1.24 to 7.4. E. W. Perkins, L. H. Jorgensen, and S. C. Sommer. *U.S., NACA Rep. 1386*, 1958. 17 pp. 19 refs. Supt. of Doc., Wash., $0.25.

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Resistance on a Sphere Due to a Circular Vortex Filament in a Uniform Flow of a Perfect Liquid. M. K. Mitra. *ZAMM*, Jan.-Feb., 1959, pp. 25–30. Derivation of a formula for the drag on a sphere due to a circular vortex filament in uniform flow of a perfect fluid.

The Magnus Characteristics of a 30 mm Aircraft Bullet. Appendix—Method of Calibration and Data Reduction for a Four Component Strain Gage Balance for Measuring Magnus and Normal Forces. A. S. Platou and J. Sternberg. *U.S., BRL Rep. 994*, Sept., 1956. 61 pp. Experimental investigation to determine the Magnus force and pitching moment of a bullet in the Mach Number range of 1.5 to 2.5. Data are presented covering angles of attack up to 40° and spin rates up to 45,000 r.p.m.

On the Viscous Flow Around the Leading Edge of a Flat Plate. B. A. Boley and M. B. Friedman. *J. Aero/Space Sci.*, July, 1959, pp. 453, 454.

The Influence of Thermal Effects on the Viscous Resistance of a Steady Uniform Flow of Liquid. S. A. Regirer. *(Prikl. Mat. i Mekh.*, May-June, 1958, pp. 414–418.) *PMM—Appl. Math. & Mech.*, No. 3, 1958, pp. 580–586. Translation.

Contribuţii la Determinarea Condiţiilor Constructive ale Profilelor Anticavitaţionale. A. Bârglăzan. *Stud. Cerc. Stiint., Ser. Stiint. Teh.*, Jan.-June, 1958, pp. 83–89. In Rumanian, with summaries in Russian and French. Application of formulas expressing the velocity and pressure distribution over a Joukowski profile to the case of an arbitrary profile. Design considerations for the minimum value of the distribution coefficient are included and the theoretical results are compared with experimental data.

O Nouă Metodă de Determinare a Caracteristicilor Hidrodinamice şi Cavitaţionale ale Reţelelor de Profile Subţiri. A. Bârglăzan and O. Popa. *Stud. Cerc. Stiint., Ser. Stiint. Teh.*, Jan.-June, 1958, pp. 73–82. In Rumanian, with summaries in Russian and French. Development of a method for determining the hydrodynamic and cavitation characteristics of cascades composed of thin profiles. The hypotheses introduced into the solution of the problem are stated, and the results of the calculation are presented.

Magnetofluidomecanica. Theodore von Kármán. *Ing. Aero.*, Nov.-Dec., 1958, pp. 50–55. In Spanish. Discussion covering the terminology used and definition of the concept of magnetofluidmechanics, as well as its role in interpreting the cosmogonic and astrophysical processes. Possible technical applications are analyzed; these include flight in the atmosphere; re-entry of hypersonic vehicles; propulsion, including the pinch effect; and acceleration of working fluid for propulsion in space vehicles.

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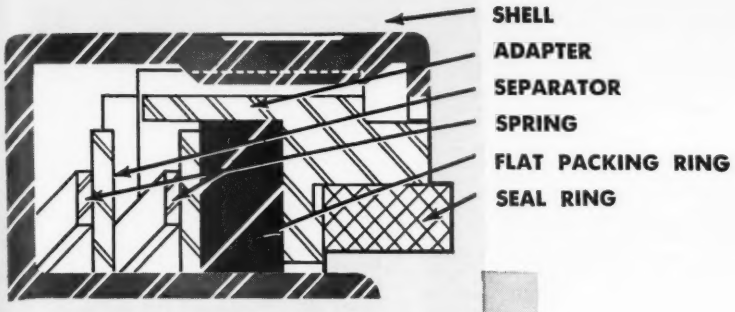

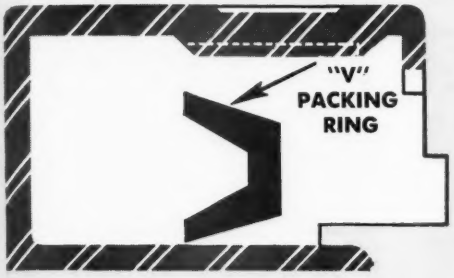

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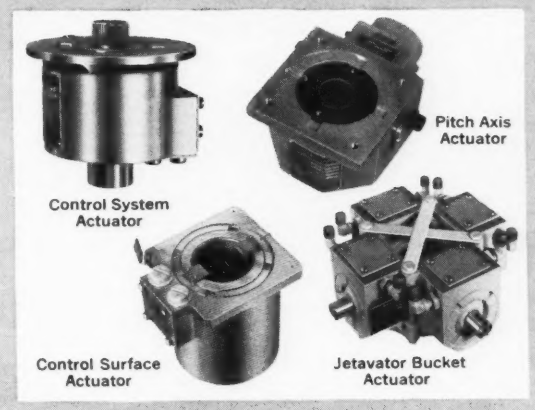

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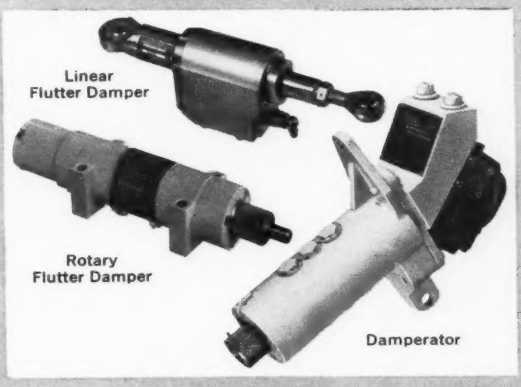

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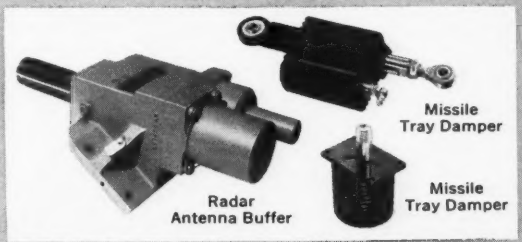

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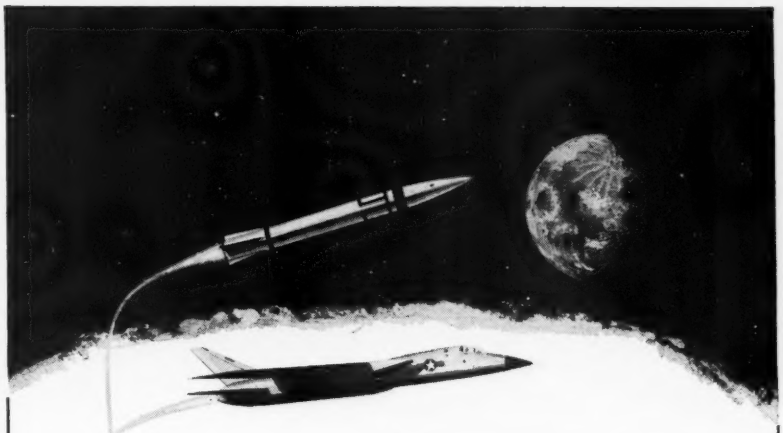

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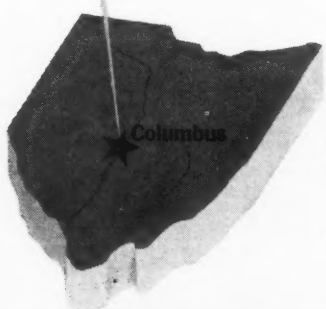

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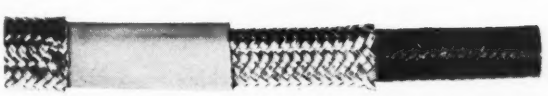

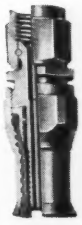

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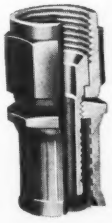

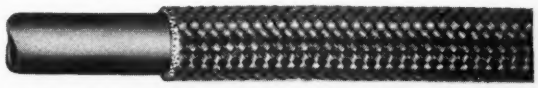

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Safe Mechanisms. Raoul Hafner. (*RAeS 1,095th Lecture, London, Jan. 8, 1959.*) *RAeS J.*, May, 1959, pp. 273–287. 12 refs. Discussion of a design philosophy for helicopter components.

Analyse und Synthese der Raumkurbelgetriebe mittels Raumliniengeometrie und dualer Grössen. M. L. Keler. *Forschung Gebiete Ing., Ausg. A*, No. 1, 1959, pp. 26–32. In German. Presentation of an analysis and synthesis of spatial linkages by line geometry of space and dual terms.

Die zweidimensionale Fourieranalyse spezieller Koppelkurven. W. Meyer zur Capellen. *ZAMM*, Jan.-Feb., 1959, pp. 31–40. 25 refs. In German. Further extension of the harmonic analysis of the equations of motion applied to determine the locus of the center of mass.

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Schrauben aus rostfreiem Stahl für die Luftfahrt. E. Richter. *Luftfahrttechnik*, Feb. 15, 1959, pp. 58–60. In German. Discussion covering the importance of stainless steel bolts for aircraft application. Various materials and their properties are listed along with manufacturing methods, and the danger of corrosion is stressed.

Gears & Cams

Analytical Design of Disk Cams and Three-Dimensional Cams by Independent Position Equations. F. H. Raven. (*ASME Annual Meeting, New York, Nov. 30–Dec. 5, 1958, Paper 58–A–17.*) *ASME Trans., Ser. E - AM*, Mar., 1959, pp. 18–24.

Mechanisms & Linkages

Study on the Mechanical Transducers for the Determination of Paths in Plane Mechanisms, in Cartesian or Polar Coordinate Systems. R. Bogdan, Cr. Pelecudi, and L. Calmaciuc. *Iaşi Politeh. Inst. Bul.*, Fasc. 1–2, 1958, pp. 315–326.

Rotating Discs & Shafts

Biegeschwingungen einer unrunden, rotierenden Welle in horizontaler Lage. W. Kellenberger. *Ing.-Arch.*, No. 4, 1958, pp. 302–318. In German. Study of the problem of flexural oscillations of a rotating shaft, reduced to the solution of a system of partial differential equations with harmonic coefficients.

Theorie und Experiment zum Reibungswiderstand der glatten rotierenden Scheibe bei turbulenter Strömung. E. Broeker. *ZAMM*, Jan.-Feb., 1959, pp. 68–76. 14 refs. In German. Evaluation of theoretical and experimental studies covering the frictional drag of rotating discs enclosed in a casing. Two specific cases are studied, and it is shown that the theory cannot be confirmed by experiment.

Kritische Drehzahlen und Biegeschwingungen kontinuierlich besetzter Wellen bei verschiedenen Lagerungen. H. Bufler and H. G. Hahn. *Ing.-Arch.*, No. 6, 1958, pp. 387–397. In German. Calculation of critical rotations and bending oscillations of continuously loaded shafts in four different arrangements.

Seals

X-15—Hydraulic Seals. *Aircraft & Missiles Mfg.*, June, 1959, p. 32. Discussion covering the application of Teflon as extrusion barrier for O-rings in the hydraulic system.

Maintenance

Equipment Maintenance with Various Numbers of Service Men: A Simple Analysis. Appendix A—**Derivation of the General Formula.** Appendix B—**Delineation of the Region of Acceptable Parameter Values.** Appendix C—**Specification of the Conditions Under Which One or More Than One Maintenance Men Should be Used.** G. O. Wright, R. L. Deininger, J. C. McGuire, and R. W. Queal, Jr. *USAF WADC TR 58-543 [AD 206921]*, Nov., 1958. 36 pp.

Automation in Aviation Ground Services. Werner Treibel. *Interavia*, May, 1959, pp. 521–523. Discussion of the advantages of automation and of operational requirements in the various ground handling aspects and in air traffic control.

Materials

Principles of Modern Materials Research. A. von Hippel. (*3rd Navy Sci. Symposium, Phila., Mar. 17–19, 1959.*) *MIT LIR TR 136*, Mar., 1959. 24 pp. 49 refs. Discussion of the approach to be used in developing materials for electronic applications. The case of an "ideal capacitor" is studied to illustrate the procedure.

Thermophysical Properties of Solid Materials. Alexander Goldsmith and T. E. Waterman. *USAF WADC TR 58-476 [AD 207905]*, Jan., 1959. 432 pp 155 refs. Data on pure elements, alloys, cermets, intermetallics, polymeric materials, and composite materials.

Some Surface Properties of Silicon-Carbide Crystals. J. A. Dillon, Jr., R. E. Schlier, and H. E. Farnsworth. *J. Appl. Phys.*, May, 1959, pp. 675–679. USAF-supported description of work-function measurements and low-energy electron-diffraction studies for several commercial-type single crystals of α silicon carbide.

Behavior of Materials in Space. J. C. Simons, Jr. *Astronautics*, June, 1959, pp. 32, 33, 84, 86, 88. Discussion of the effects of a space environment on the properties of materials and the need for laboratory techniques to study these effects under similar conditions as would be encountered in space.

Ceramics & Ceramals

Ceramics and Glass and Their Application in Modern Aeronautics. L. Zagar. (*NATO AGARD 7th Structures & Materials Panel, Rome, Mar. 24–Apr. 3, 1958.*) *NATO AGARD Rep. 179*, Apr., 1958. 15 pp. 10 refs.

Metal-Ceramic Laminates. R. K. Francis, R. Brown, E. P. McNamara, and J. R. Tinklepaugh. *USAF WADC TR 58-600 [AD 205549]*, Nov., 1958. 69 pp. 45 refs. Review of methods for forming ceramic-metal laminates. Forsterite-stainless steel 430, molybdenum-alumina, and Kovar-alumina were fabricated employing brazing techniques. Laminates of molybdenum and 40 per cent alumina-60 per cent mullite ceramic were hot-pressed.

An Investigation of the Mechanical Properties of Cermets as Related to the Microstructure. Ira Binder and Robert Steinitz. *USAF WADC TR 58-432 [AD 208148]*, Jan., 1959. 86 pp.

Zirconia: Its Crystallographic Polymorphy and High Temperature Potentials. B. C. Weber and M. A. Schwartz. *USAF WADC TR 58-646 [AD 206908]*, July, 1958. 21 pp. 21 refs.

Corrosion & Protective Coatings

Some Fundamental Features of Mechano-Chemical Attack on Metals. T. P. Hoar. (*NATO AGARD 6th Structures & Materials Panel, Paris, Nov. 4–8, 1957.*) *NATO AGARD Rep. 158*, Nov., 1957. 5 pp. Discussion of the effects of fretting and stress corrosion, as well as of ordinary and corrosion fatigue on oxide films.

External Deposits and Corrosion in Boilers and Gas Turbines. B. A. Landry. (*ASME Annual Meeting, New York, Nov. 30–Dec. 5, 1958, Paper 58–A–208.*) *Mech. Eng.*, June, 1959, pp. 70–73. Study covering the origin of deposits and the mechanism of their growth, the formation of SO_3, the removal of fuel impurities, and corrosion prevention.

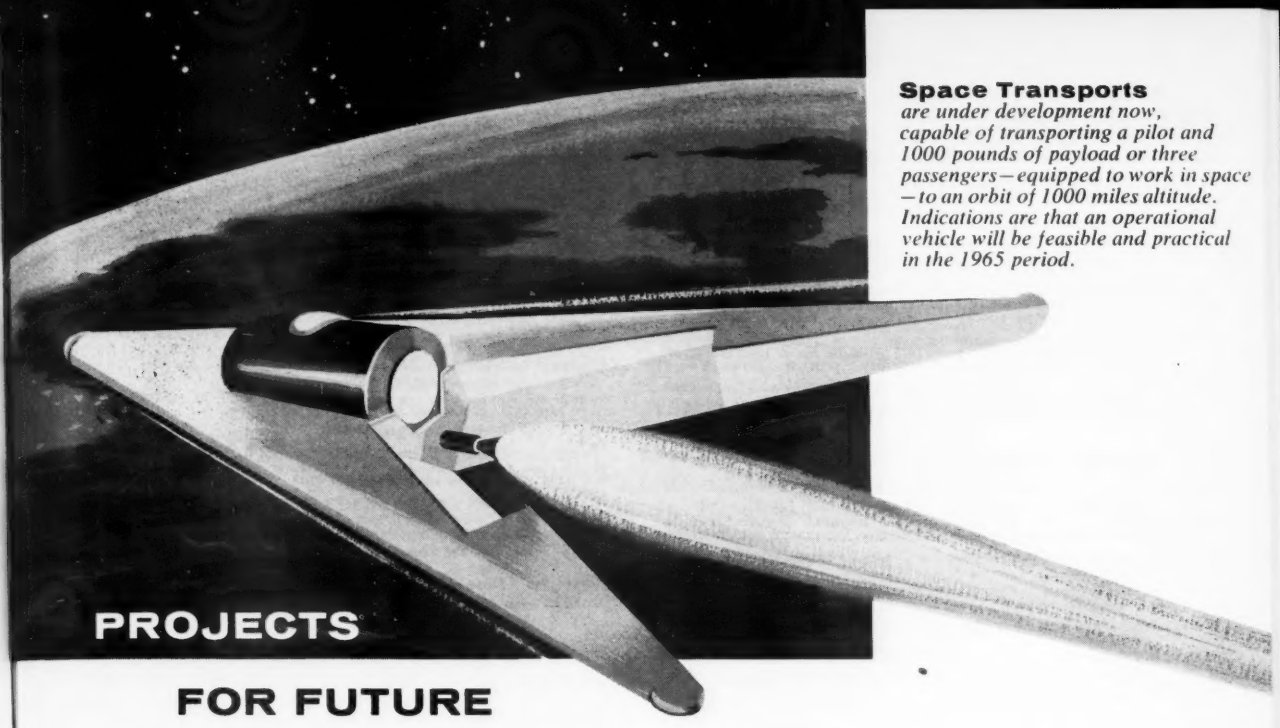
Research for Coatings for Protection of Niobium Against Oxidation at Elevated Temperatures. E. C. Hirakis. *USAF WADC TR 58-545 [AD 209914]*, Feb., 1959. 64 pp. 16 refs.

Development and Evaluation of Rocket Blast and Rain Erosion Resistant Composite Coatings Produced by Flame Spray Techniques. J. R. Galli, G. I. Wheeler, B. H. Clampitt, D. E. German, and R. B. Johnson. *USAF WADC TR 58-43 [AD 209913]*, Feb., 1959. 227 pp. 497 refs.

High Temperature

Selection of Materials for Hypersonic Leading-Edge Applications. F. M. Anthony and H. A. Pearl. (*IAS Natl. Summer Meeting, Los Angeles, June 16–19, 1959, Paper 59–111.*) *Aero/Space Engrg.*, July, 1959, pp. 40–43, 62. USAF-supported analysis showing the relationship of material and design considerations in a hypersonic leading edge and the use of these relationships for material selection. Environmental conditions, material requirements, and methods for establishing data for various materials are considered.

(Continued on page 98)



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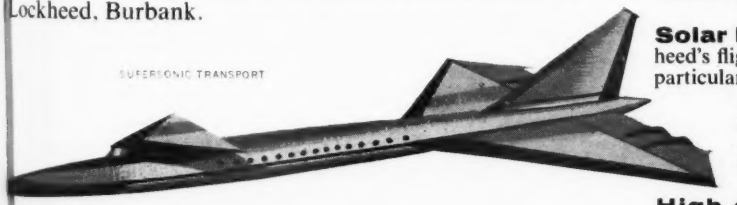

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PUBLISHED MONTHLY BY AERO/SPACE ENGINEERING

Official Publication of the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

Volume 4, Number 8 August, 1959

ACOUSTICS, SOUND, NOISE

THE EFFECT OF JET NOISE ON AIRCRAFT STRUCTURES. B. L. Clarkson. Aero. Quart., May, 1959, pp. 103-126. 40 refs. Review of the present state of knowledge on the problem of fatigue failure due to vibrations excited by jet noise. The following aspects are studied in detail: (1) general theory of structural response to random pressure loads, (2) characteristics of the noise pressure field, (3) mechanical impedance of the aircraft structure, (4) practical approximations to the general case by considering panel vibrations, and (5) fatigue life estimation. It is concluded that it should currently be possible to make reasonable estimates of the stress levels set up in a structure by jet noise but, in general, the resultant fatigue life of the components cannot be estimated with any confidence.

AERODYNAMICS, FLUID MECHANICS

I - DIE AERODYNAMIK DES TRANSSONISCHEN FLUGES. II - DIE AERODYNAMIK DES HYPERSONISCHEN FLUGES. III - DETAILPROBLEME DES TRANSSONISCHEN FLUGES. E. J. Kordik. Der Flieger, Mar.; Apr.; May, 1959, pp. 92-94; 124-127; 167-169. In German. Detailed survey of aerodynamic problems in transonic and hypersonic flight. Considered are the laminar profiles and fuselages, transonic designs, and swept and delta wings, as well as the high Mach Number region, compression waves, Mach cones, and the sonic boom phenomenon. Also includes discussion of the area rule concept, as well as study of temperature and stability and control problems.

Aerothermochemistry, Dissociation, Ablation

REACTION RATE DISTRIBUTIONS ON CATALYTIC SURFACES. D. E. Rosner. AeroChem Res. Lab. TM 12 (AFOSR TN 59-432) [AD 214794], Dec. 26, 1958. 7 pp. Application of Ambrok's nonsimilarity correction to the Nusselt Number to the diffusion boundary layer with catalytic surface reaction. For the laminar boundary layer on a catalytic flat plate, closed form results are obtained for the steady state reactant concentration along the surface, and hence the reaction rate distribution, for arbitrary values of the reaction order.

EFFECT OF DISSOCIATION ON THE PERFORMANCE OF WORKING FLUIDS FOR NUCLEAR PROPULSION. J. G. Logan and E. L. Colichman. ARS J., June, 1959, pp. 409-413. USAF-sponsored derivation of general enthalpy relations for an idealized diatomic gas in order to investigate the effect of molecular weight, dissociation energy, and pressure on the performance of diatomic working fluids. It is shown that maximum performance for a given molecular weight should be obtainable from molecules with bond energies in the range of 1.5 to 2.5 ev. The influence of pressure on dissociation is also indicated. The results of the study for the diatomic system also indicate desirable ranges of molecular weight and bond energy for more complex molecular systems.

Aerothermodynamics

A SIMPLE METHOD FOR DETERMINING HEAT TRANSFER, SKIN FRICTION, AND BOUNDARY-LAYER THICKNESS FOR HYPERSONIC LAMINAR BOUNDARY-LAYER FLOWS IN A PRESSURE GRADIENT. Appendix - DERIVATION OF THE HYPERSONIC EQUATIONS FOR SKIN FRICTION, HEAT TRANSFER, AND BOUNDARY-LAYER THICKNESS. M. H. Bertram and W. V. Feller. US, NASA Memo. 5-24-59L, June, 1959. 60 pp. 29 refs. Presentation of a method of similar solutions by which the boundary-layer effects in a laminar hypersonic flow may be rapidly evaluated if the pressure distribution is known. This solution, which at present is restricted to power-law variations of pressure with surface distance, is given for a wide range of exponents in the power law corresponding to both favorable and adverse pressure gradients. This theory is compared with results

from heat-transfer experiments on blunt-nose models at free-stream Mach Numbers of 4 and 6.8, including tests at angles of attack.

AN INVESTIGATION OF LAMINAR, TRANSITIONAL AND TURBULENT HEAT TRANSFER ON BLUNT-NOSED BODIES IN HYPERSONIC FLOW. R. J. Cresci, D. A. MacKenzie, and P. A. Libby. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech. Rep. (USAF WADC TN 59-119) [AD 214617], Apr., 1959. 50 pp. 26 refs. Measurement of heat transfer data using the shrouded model technique for a wide range of Reynolds Numbers with enthalpy ratios on the order of two. Comparison with theoretical predictions shows that the flat-plate reference-enthalpy method provides a simple and relatively accurate means for estimating heat rates in fully developed turbulent flow. A rational method of permitting the inclusion of transition behavior and transitional heat-transfer rates has been suggested and shown to be fairly accurate. The predictions for fully developed turbulent flow from this method are also reasonably accurate and relatively simple to obtain.

EXPERIMENTAL DETERMINATION OF THE TURBULENT HEAT TRANSFER RATE DISTRIBUTION ALONG A SLENDER BLUNT NOSED BODY FROM SHOCK TUBE TESTS. E. Offenhartz and H. Weisblatt. Avco Res. & Adv. Devel. Div. RAD TR 9-59-18, May 25, 1959. 24 pp. USAF-sponsored investigation made at zero and non-zero angle of attack to correlate various theories with experimental results. At zero-degree angle of attack it was found that the Van Driest and momentum turbulent flow theories predict the trend of the experimental data for the entire body. At angle of attack, the heat transfer data were correlated in terms of the ratio of measured heat transfer rates at angle of attack to zero values. A simple engineering approach permits the calculation of this ratio which closely predicts the trend of experimental data.

EXPERIMENTAL INVESTIGATION OF THE HEAT-TRANSFER RATE TO A SERIES OF 20° CONES OF VARIOUS SURFACE FINISHES AT A MACH NUMBER OF 4.95. J. J. Jones. US, NASA Memo. 6-10-59L, June, 1959. 26 pp. Results of tests conducted in an axisymmetric Mach Number 4.95 blowdown jet at free-stream Reynolds Numbers per ft. varying from 20×10^6 to 100×10^6. The range of the surface finish was from a very smooth polish to smooth machining with no polish (65 microin. r.m.s.). The results indicate that the turbulent heat-transfer rate for the highest roughness tested is only slightly greater than that for the smoothest surface. The laminar-sublayer thickness is calculated to be about half the roughness height for the roughest model at the highest value of unit Reynolds Number tested. Although some laminar boundary-layer data are obtained, main emphasis is placed on the turbulent boundary layer of special interest in the selection of the surface finish for hypersonic vehicles.

DISTRIBUTION OF HEAT TRANSFER ON A 10° CONE AT ANGLES OF ATTACK FROM 0° TO 15° FOR MACH NUMBERS OF 2.49 TO 4.65 AND A SOLUTION TO THE HEAT-TRANSFER EQUATION THAT PERMITS COMPLETE MACHINE CALCULATIONS. Appendix - DEVELOPMENT OF A SOLUTION TO THE HEAT-TRANSFER EQUATION THAT PERMITS COMPLETE MACHINE CALCULATION. P. B. Burbank and B. L. Hodge. US, NASA Memo. 6-4-59L, June, 1959. 45 pp. Presentation of results of an experimental heat-transfer investigation to be used in the design of aerodynamic or ballistic missiles. The measured laminar heat-transfer coefficients at an angle of attack of 0° are in good agreement with Van Driest theory having a Mangler transformation. At angle of attack the heat-transfer coefficient along the stagnation line is 1.9 to 4 times greater than at an angle of attack of 0° depending upon the distance from the tip of the nose, Reynolds Number, and Mach Number. Boundary-layer transition and body vortices caused minimum heat-transfer coefficients to occur at the 90° and 120° meridian angles and increased aerodynamic heating along the 180° meridian that in some cases is of the same magnitude as that along the zero meridian (stagnation line).

MEASUREMENTS OF HEAT TRANSFER AND RECOVERY TEMPERATURE IN REGIONS OF SEPARATED FLOW AT A MACH NUMBER OF 1.8. H. Thomann. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 82, 1959. 28 pp. 34 refs. Measurement of heat transfer, recovery temperature, skin friction, and pressure distribution at a Reynolds Number of 10^7. The influence of separation on heat transfer and recovery temperature was remarkably low. The measurement of the skin friction showed that it is impossible to apply the Reynolds analogy without further knowledge of the flow field.

AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF EJECTING A COOLANT GAS AT THE NOSE OF A BLUNT BODY. C. H. E. Warren. GALCIT HRP Memo. 47, Dec. 15, 1958. 118 pp. Army-sponsored study to determine the effect of nitrogen and helium coolant gases at the nose of a blunt body on local heat transfer rates and to explore the effects of incidence. It was found that ejection with swirl did not lead to an abatement of the heating problem because the high tangential velocity with which the coolant was injected into the boundary layer so increased the wall shear stress, and hence by the Reynolds analogy, the heat flux, that it predominated over the reduced driving temperature difference associated with the cooled boundary layer. With straight-out ejection it was found that the heat alleviation capabilities of the ejected coolant were reduced considerably if the momentum flow was sufficiently high to make the bow shock wave bulge out. The results suggest that straight-out ejection could provide an effective way of reducing the heat flux provided that the external flow is not disturbed.

Boundary Layer

NUMERICAL SOLUTION OF THE BOUNDARY-LAYER EQUATIONS WITHOUT SIMILARITY ASSUMPTIONS. R. F. Kramer and H. M. Lieberstein. J. Aero/Space Sci., Aug., 1959, pp. 508-514. Application of the Crocco transformation combined with the Mangler transformation to modify the boundary-layer problem for axially symmetric blunt bodies into a form suitable for direct numerical computation without introduction of similarity assumptions. Data can be generated on the stagnation line (perpendicular to the body) to serve as initial values, and since the equations are a parabolic system of two second-order equations, the boundary-value problem is analogous to the slab problem for the heat equation. An implicit difference equation is used to reduce stability difficulties. For blunt-nosed bodies with approach flow Mach Numbers greater than eight, large temperature gradients occur across a thin boundary layer of dissociated gas, and it is necessary to use real-gas effects. A case is computed for a lower Mach Number approach flow using perfect-gas theory to provide a standard against which similarity solutions may be tested.

THE EFFECT OF CENTRIFUGAL FORCES ON BOUNDARY LAYER TRANSITION FOR A HIGHLY HEATED BODY. Eugene Sevigny and Marian Visich, Jr. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech. Rep. (USAF WADC TN 59-121) [AD 214620], Mar., 1959. 38 pp. Experimental investigation conducted in a $M = 3.75$ wind tunnel using a hemispherically blunted 20° half-angle cone having a density ratio of approximately four along the conical region, and a maximum centripetal acceleration at the centerline of the model of 300 g's. Tests covered a range of free-stream Reynolds Number per ft. of 22.2 to 51.9×10^6. Results indicate that the effect of high centrifugal force on the stability of the laminar boundary layer is negligible. The transition Reynolds Number based on momentum thickness was approximately 600 for all tests.

METHODS OF BOUNDARY-LAYER CONTROL FOR POSTPONING AND ALLEVIATING BUFFETING AND OTHER EFFECTS OF SHOCK-INDUCED SEPARATION. H. H. Pearcey and C. M. Stuart. (IAS Natl. Summer Meeting, Los Angeles, June 16-19, 1959.) IAS SMF Fund Paper No. FF-22, 1959. 72 pp. 39 refs. Members, $1.50; nonmembers, $3.00. Discussion of the factors influencing the choice of boundary-layer control emphasizing the need to maintain effectiveness over most of the chord to cover the wide range of separation positions encountered as the shock moves over the wing with changing flight conditions. High-velocity blowing, vane and air-jet vortex generators, and distributed suction are briefly described. For vortex generators, the importance is stressed of the vortex path determined by the interactions of neighboring vortices and their images. Thus, systems of counterrotating vortices always leave the surface in pairs and lose their effectiveness. Corotating systems are therefore preferred for many applications. Blowing, which in wind tunnel tests gives results as good as, or better than, vortex generators and does not have the disadvantage of a drag penalty at cruise, has not yet been assessed in flight. Air-jet vortex generators, which would also avoid the drag penalty, show promise of producing significant effects with relatively small blowing pressures and quantities.

THE RESPONSE OF LAMINAR BOUNDARY LAYER TO IMPULSIVE MOTIONS. M. L. Rosenzweig. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 59-92) [AD 210182], Feb., 1959. 96 pp. 26 refs. Analysis of the stagnation-point flow against a wall moving impulsively in its own plane. A method of solution, based on the works of Rott and Glauert, is developed and applied to the case of linearized, unsteady, laminar boundary-layer flow. The results can be applied to the boundary layers of flows about cylindrical bodies with arbitrary cross section. Detailed calculations are carried out to determine the oscillatory response of the laminar boundary layer when the basic steady flow is that given by the potential velocity distribution $U_\infty = cx^m$. The calculated results are then used to find the response to impulsive changes of velocity. Velocity profiles are numerically computed for three special values of m and the results are plotted. Schuh's method for the calculation of unsteady boundary-layer problems is described and discussed, and some of the simplifications and limitations of the method are pointed out.

CHARTS AND TABLES FOR ESTIMATING THE STABILITY OF THE COMPRESSIBLE LAMINAR BOUNDARY LAYER WITH HEAT TRANSFER AND ARBITRARY PRESSURE GRADIENT. Neal Tetervin. US, NASA Memo. 5-4-59L, May, 1959. 48 pp. 10 refs. Calculation of the minimum critical Reynolds Numbers for similar solutions of the compressible laminar boundary layer by Lin's rapid approximation method. These results enable the stability of a boundary layer with heat transfer and pressure gradient to be easily estimated after the behavior of the boundary layer has been computed by the approximate method of Cohen and Reshotko. A favorable pressure gradient is found to be destabilizing for very cool walls.

AN UNSTEADY TURBULENT BOUNDARY LAYER. S. K. F. Karlsson. J. Fluid Mech., May, 1959, pp. 622-636. Study of a low-speed parallel flow whose velocity fluctuates sinusoidally in magnitude about a constant mean. Hot wire measuring techniques are developed to permit an investigation of the turbulent boundary layer developing on a flat plate with this free stream condition. The response of the layer at a Reynolds Number of 3.6×10^3 was measured for free stream fluctuation amplitudes up to 34% of the mean velocity and frequencies ranging from zero to 48 cps. Measurements are made of the mean velocity, the amplitudes of in- an out-of-phase components of the first harmonic of the periodic

fluctuations, and of the intensity of higher harmonics and turbulence. It was found that nonlinear effects at the largest fluctuation amplitudes were so small that they were obscured by experimental errors.

Flow of Fluids

ON THE INTEGRAL OF MOMENT OF PRESSURE IN SUPERSONIC FLOW. Lu Ting. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 449 (AFOSR TN 59-358) [AD 213684], May, 1959. 15 pp. Analysis showing that the integral of the moment of the disturbance pressure along the line of interaction of a Mach plane with the cylindrical surface, whose generator is parallel to the undisturbed stream, is related to the integral of the moment of the prescribed normal velocity along the same line. Its applications in problems of planar systems and wing-body combinations at supersonic speed are discussed.

SOURCE DISTRIBUTION METHOD FOR UNSTEADY ONE-DIMENSIONAL FLOWS WITH SMALL MASS, MOMENTUM, AND HEAT ADDITION AND SMALL AREA VARIATION. Appendix A, B - ELEMENTAL SOURCE SOLUTION FOR M > 1. Appendix C - TRANSFER FUNCTIONS. Harold Mirels. US, NASA Memo. 5-4-59E, June, 1959. 49 pp. 12 refs. Development of a source distribution method for obtaining flow perturbations in uniform one-dimensional flow. First, the perturbations due to an elemental area variation, mass, momentum, and heat addition are found. The general solution is then represented by a spatial and temporal distribution of these elemental (source) solutions. Several examples presented include (1) a shock propagating through a nonuniform tube, (2) a constant-velocity piston driving a shock, (3) ideal shock-tube flows, and (4) deflagrations initiated at a closed end.

ON THE STABILITY OF VISCOUS FLUID MOTIONS. James Serrin. Arch. Rational Mech. & Anal., Mar. 24, 1959, pp. 1-13. 14 refs. Determination of sufficient conditions for the basic flow of an incompressible fluid to be stable under arbitrary disturbances, using the energy method of Reynolds and Orr. A Reynolds Number criterion for the stability of an arbitrary fluid motion is obtained. In particular, it is shown that a bas ic flow in a bounded region $\mathcal{V}$ is stable whenever its Reynolds Number is less than 5.71. Similar criteria for the stability of flows in unbounded regions are also obtained and applications made to the problem of uniqueness of steady flow. A general variational problem connected with the stability of an arbitrary motion is stated and the laminar Couette flow between rotating coaxial cylinders is studied using the previous method and the variational techniques.

EFFECT OF BUOYANCY FORCES ON CERTAIN VISCOUS FLOWS WITH SUCTION. A. S. Gupta. Appl. Sci. Res., Sect. A, No. 4, 1959, pp. 309-320. Analysis of the effect of gravity on the unsteady flow of a viscous incompressible fluid due to the motion of an inclined porous flat plate along its line of greatest slope. The boundary-layer equations are integrated for two cases: (1) when the suction velocity at the plate is constant, (2) when the suction velocity at the plate is inversely proportional to the square root of time. Explicit expressions for velocity and temperature distribution are given in both cases for any Prandtl Number. Analysis is also made for the case of free convection flow of a compressible fluid past a flat plate, and it is found that the skin friction at the plate increases with gravity and decreases with suction.

K TEORII GAZOVYKH STRUI. L. N. Sretenskii. Prikl. Mat. i Mekh., Mar.-Apr., 1959, pp. 305-332. In Russian. Analysis covering the solution of various problems in the theory of gas flows. The cases studied include the concentration of gas streams and the flow around plates, assuming the formation of a region of zero gas velocity ahead of the plate. The common characteristic of these two cases is analyzed. The third case covers problems of gas jets solved by means of Chaplygin's integrals.

HYPERSONIC FLOW OVER AN ELLIPTIC CONE: THEORY AND EXPERIMENT. R. L. Chapkis. GALCIT HRP Memo. 49, May 1, 1959. 44 pp. 12 refs. Army-sponsored application of hypersonic approximations to Ferri's linearized characteristics method to obtain the shock shape and surface pressure distribution for an unyawed conical body of arbitrary cross section. Calculations are carried out for an elliptic cone having a ratio of major to minor axis of 2:1, and a semi-vertex angle of about 12° in the meridian plane containing the major axis. An experimental investigation of the flow over this body conducted at a Mach Number of 5.8 shows that the surface pressure distribution at zero angle of attack agreed quite closely with the theoretical prediction. The simple Newtonian approximation, however, predicts pressures that are too low. Surface pressure distributions and schlieren photographs of the shock shape were also obtained at angles of attack up to 14° at zero yaw, and at angles of yaw up to 10°, at zero pitch. At higher angles of attack the Newtonian approximation for the surface pressures is quite accurate.

THE ELLIPTIC CYLINDER IN A SHEAR FLOW WITH HYPERBOLIC VELOCITY PROFILE. E. E. Jones. Quart. J. Mech. & Appl. Math., May, 1959, pp. 191-210. 13 refs. Presentation of the shear flow as an infinite series of Mathieu functions. It is found that the stagnation streamline of the flow is displaced toward a region of higher velocity, this displacement increasing (1) with increase of angle of incidence of the cylinder to main stream, (2) as the stream becomes progressively nonuniform, (3) with increase of minor axis length when the major axis length remains invariant. In each case the dis-

placement reaches a limiting value as the cylinder moves away from the axis of symmetry of the stream. These limiting values are reached at critical distances from the axis of symmetry, which decrease as the stream becomes progressively nonuniform, but these distances are approximately independent of incidence. The pressure coefficients and the resultant force and moment coefficients associated with the cylinder are obtained.

FLUID-DYNAMIC PROPERTIES OF SOME SIMPLE SHARP- AND BLUNT-NOSED SHAPES AT MACH NUMBERS FROM 16 TO 24 IN HELIUM FLOW. Arthur Henderson, Jr., and P. J. Johnston. US, NASA Memo. 5-8-59L, June, 1959. 63 pp. 27 refs. Investigation of the fluid-dynamic characteristics of flat plates and 5° and 10° wedges and cones. The flat-plate results are for a leading-edge Reynolds Number range of 584 to 19,500 and show that the induced pressure distribution is essentially linear. It is also shown that the rate at which the induced pressure varies with the hypersonic viscous interaction parameter $\bar{X}$ is a linear function of the leading-edge Reynolds Number. The wedge and cone results show that as the flow-deflection angle increases, the induced-pressure effects decrease and the measured pressures approach those predicted by inviscid shock theory.

LIMIT CYCLES FOR NON-SPINNING STATICALLY STABLE SYMMETRIC MISSILES. Appendix A - THE GENERALIZED AERODYNAMIC MOMENT FOR A BODY OF REVOLUTION. Appendix B - CHARACTER OF PURE MODE SINGULARITIES. Appendix C - AN AERODYNAMIC INTERPRETATION OF THE NEW TERMS FOR A SLENDER BODY. Ch. H. Murphy. US, BRL Rep. 1071, Mar., 1959. 37 pp. 11 refs. Investigation of possible nonlinearities which could produce circular limit motions on nonspinning bodies of revolution with low fineness ratios. The influence of such nonlinearities which are cubic in the angles and angular velocities are described. The most general cubic moment with both angles and angular velocities is considered in detail and corresponding amplitude planes are constructed. Estimates of the coefficients of the new terms are made by means of an extension of the Allen-Kelley cross flow analogy.

THE TWO-DIMENSIONAL LAMINAR FLOW NEAR THE STAGNATION POINT OF A CYLINDER WHICH HAS AN ARBITRARY TRANSVERSE MOTION. J. Watson. Quart. J. Mech. & Appl. Math., May, 1959, pp. 175-190. Brief study of the reaction of an arbitrary boundary layer to arbitrary changes in the free-stream velocity. Then, exact solutions of the Navier-Stokes equations are derived for two-dimensional flow against an infinite flat plate normal to the stream and performing an arbitrary transverse motion. This generalizes Glauert's solution for an oscillating transverse motion. When the wall moves from rest, then, by means of a Laplace-transform technique, expansions of the velocity distribution for small and large times are given in terms of the velocity of the wall. Further, it is indicated how a Pohlhausen type of method may always be used to obtain an approximate solution for the purpose of linking up these expansions across the range of times for which neither is valid. The method may also be used for motions other than those starting from rest.

HIGH SUBSONIC FLOW WITH NORMAL SHOCK WAVE AT NEARLY CRITICAL MACH NUMBER. Takeo Sakurai. Phys. Soc. Japan J., May, 1959, pp. 658-663. Presentation of a simple approximation procedure for determining the high subsonic flow past a biconvex circular arc airfoil. The shock waves are assumed to be the normal shock waves which start from the surface of the airfoil and stand perpendicularly to the direction of the uniform flow. The locations of the sonic line and the shock waves are treated as unknown parameters and are shown to have real physical meaning only when the Mach Number exceeds the usual critical Mach Number calculated by means of the Prandtl-Glauert approximation. Results suggest that the curvature of the profile must change discontinuously at its intersection with the shock wave, a fact which is confirmed by applying Lin's exact consideration. Thus, it is concluded that there can exist no high subsonic flow of ideal fluid with normal shock waves starting from the surface past a profile having continuous curvature.

RICERCA SULL'OGIVA DI MINIMA RESISTENZA D'ONDA. I. Dante Cunsolo. L'Aerotecnica, Feb., 1959, pp. 7-13. In Italian. Application of the variational method developed by Ferrari to the study of minimum wave-drag profiles, showing that the shock produced by the body does not cross the axis of symmetry. The profile has first a hollow part, at high pressure, followed by a convex one, with a considerable reduction of corresponding pressures. Some results obtained with the method of supersonic sources are presented. The study was carried out for $M = 2$ and a length of 5 diam.

A METHOD OF SOLUTION OF THE EQUATIONS OF MAGNETOHYDRODYNAMICS. Judith Blankfield and G. C. McVittie. Arch. Rational Mech. & Anal., Feb. 4, 1959, pp. 411-422. Solution of equations describing the motion of a gas cloud with infinite plane faces normal to the direction of motion, the forces being the pressure gradient and a magnetic force parallel to the faces. The theory depends on degenerating Einstein's equations of general relativity. In this method, the indeterminate functions are known to be degenerate forms of the generalized potentials of Newtonian theory. The pressure and density vanish on the plane faces, the motion is adiabatic, and the ratio of specific heats has the value of 1.5. The gas cloud expands, but not beyond a certain finite width. Ultimately, the binding effect of the magnetic field balances the disruptive effect of the pressure gradient, and the cloud approaches equilibrium.

ZADACHI OBTEKANIIA V MAGNITNOI GIDRODINAMIKE. M. D. Ladyzhenskii. Prikl. Mat. i Mekh., Mar.-Apr., 1959, pp. 292-298. In Russian. Study of the flow around a body whose internal magnetic field is generated by an electrically conducting liquid. The solution is derived for large and infinite values of the magnetic Reynolds Number. The presence of magnetic forces which act upon the body and are analogous to viscous friction and profile drag is indicated. The particular case studied covers the electric as well as the magnetic internal field, and it is shown that the flow around the body is not affected by the internal electric field sources.

TEORIIA MAGNITNOGO POGRANICHNOGO SLOIA. V. N. Zhigulev. AN SSSR Dokl., Feb. 11, 1959, pp. 1,001-1,004. In Russian. Development of the theory of magnetic boundary layers and presentation of examples illustrating the phenomenon occurring in moving plasma. The case of a semi-infinite plate in a conducting fluid at rest is studied for varying directions of the electric current. The pressure across the magnetic boundary layer is calculated and it is shown that the moving plasma tends to separate from the outer magnetic field and the electric currents passing through it. In the case of motion at high magnetic Reynolds Numbers, the thickness of the layer is of the order of $1/\sqrt{Re_m}$.

THE STABILITY OF SHOCK WAVES IN MAGNETOHYDRODYNAMICS. S. I. Syrovatskii. (Zhurnal Teoret. i Exper. Fiz., Dec., 1958, pp. 1,466-1,470.) Sov. Phys. - JETP, June, 1959, pp. 1,024-1,027. Translation. Investigation of the interaction between shock waves in a magnetic field and magnetohydrodynamic waves of small amplitude. The condition for stability with respect to spontaneous emission of weak magnetohydrodynamic waves by a shock wave are obtained. The conditions are found for which the linear equations for a small perturbation have no solution, this case being interpreted as the decay of the shock wave.

SOME PROBLEMS IN HYDROMAGNETICS. K. P. Chopra. USCEC Rep. 56-205 (AFOSR TN 59-265) [AD 212468], Jan. 31, 1959. 210 pp. 85 refs. Analyses of some topics in magnetohydrodynamics including induction drag of a sphere moving in a conducting fluid, flow in a circular pipe, change in energy of a magnetic sphere, radial adiabatic pulsations of an infinite cylinder in a magnetic field, the tunnel effect, and three problems in compressible hydromagnetic flow.

REMARKS ON ROCKET AND AERODYNAMIC APPLICATIONS OF MAGNETOHYDRODYNAMICS CHANNEL FLOW. T. A. Wilson. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 58-1068) [AD 207228], Dec., 1958. 55 pp. Development of the equations of magnetohydrodynamic flow and application of the results to rocket propulsion with unlimited energy supply. The gravity-free chemical-fuel rocket equations are analyzed. The maximum payload velocity is obtained by programing the exhaust velocity; this involves storing energy during part of the rocket flight. The conditions are given for maximizing payload energy of a rocket by replacing fuel by nonenergetic, high-density material. A magnetohydrodynamic generator converting the kinetic energy of a gas into electrical energy is described along with a magnetohydrodynamic hypersonic wind tunnel and diffuser. The latter is much less efficient than the geometrical diffusers, but power lost by the fluid in the diffuser may be used in another part of an engine cycle with possible net advantages.

ON THE FLOW OF A CONDUCTING FLUID PAST A MAGNETIZED SPHERE. G. S. S. Ludford and J. D. Murray. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-169 (AFOSR TN 59-424) [AD 214774], Apr., 1959. 20 pp. Study of the first-order effects of the magnetic field and conductivity in the steady flow of an incompressible, inviscid, conducting fluid past a magnetized sphere. This leads to a regular perturbation in β, the ratio of magnetic pressure to the free-stream dynamic pressure. Parabolic wakes of vorticity and magnetic intensity are formed, the former being half the size of the latter. The vorticity, generated by the nonconservative electromagnetic force is shown to be logarithmically infinite on the sphere. Drag on the sphere derives from two sources, the fluid pressure and the Maxwell stress. The drag coefficient is derived for the dipole case in which there is no contribution from the pressure.

STOCHASTIC THEORY OF TRANSPORT PHENOMENA IN A REACTING PLASMA AT EXTREME TEMPERATURES. Appendix A - EQUILIBRIUM PROPERTIES AND COMPOSITION OF PLASMAS. Appendix B - ANALYTICAL EXPRESSIONS FOR ZERO-ORDER COLLISION INTEGRALS. Appendix C - ALTERNATE METHOD FOR TREATING COLLISION INTEGRALS IN THE TRANSPORT EQUATIONS. H. J. Kaeppeler. Forschungsinst. Phys. Strahlantriebe Mitteil. 15 (USAF WADC TR 58-353) [AD 155704], Mar., 1958. 115 pp. 28 refs. Extension of Grad's method, including the presence of electric and magnetic fields, to the case of a nonisothermal multi-component reacting plasma. The analysis deals with some fundamental concepts, such as the coordination of a continuous point manifold with a system of discrete events, definition of the generalized transport equation, and the Hamiltonian for a system of charged particles with external fields.

THEORY OF SPATIALLY GROWING PLASMA WAVES. Masao Sumi. Phys. Soc. Japan J., May, 1959, pp. 653-657. Investigation of the linearized theory of spatially growing waves in a uniform plasma. Characteristics of excited waves are presented by solving the dispersion relation. The growth-rate and the phase-veloci-

ty of amplified waves are examined in connection with the frequency and various conditions of the medium plasma and the directed beam. A comparison of the theory with experimental results shows good agreement.

SOME COMMENTS ON WAVE PROPAGATION AND SHOCK WAVE STRUCTURE WITH APPLICATION TO MAGNETOHYDRODYNAMICS. G. B. Whitham. Commun. on Pure & Appl. Math., Feb., 1959, pp. 113-158. ONR-sponsored analysis and discussion of linear and nonlinear problems in wave theory that is extended to magnetohydrodynamics. General solutions are presented for linearized equations of magnetohydrodynamics, but for nonlinear equations, the following specific cases are treated: (1) the effects of nonlinearity on wave propagation, (2) shock structure, and (3) boundary conditions and boundary layers.

INTERFERENCE OF BODY AND TRAILING EDGE VORTEX SHEET IN SUPERSONIC FLOW. Appendix - INTEGRATION OF DISTURBANCE PRESSURE ON THE FICTITIOUS PLANE. Shinya Kobayakawa and Lu Ting. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 516 (AFOSR TN 59-453) [AD 215028], May, 1959. 28 pp. Study showing that a generalized integral relationship, derived previously to relate the integral of the pressure to the normal component of the velocity on the region of a cylindrical surface ahead of a Mach plane, is still valid if the region ahead of a Mach plane contains a vortex sheetlike discontinuity surface -- i.e., a cylindrical surface with generator parallel to the undisturbed flow and across which the pressure and normal velocity are continuous.

AERODYNAMICS OF WINGS AND BODIES AT TRANSONIC SPEEDS. J. R. Spreiter. (8th Jap. Natl. Congr. Theoret. & Appl. Mech., Tokyo, Sept. 6-8, 1958.) J. Aero/Space Sci., Aug., 1959, pp. 465-486, 517. 67 refs. Presentation of summary of basic concepts and principal results that have emerged from numerous experimental and theoretical investigations of transonic flow past thin wings and slender bodies. Emphasis is placed on the correlation and evaluation of results provided by diverse methods for the approximate solution of the nonlinear equations of the small disturbance theory of transonic flow, and also on a critical examination of experimental results.

THE STRUCTURE OF ISOTROPIC TURBULENCE AT VERY HIGH REYNOLDS NUMBERS. R. H. Kraichnan. J. Fluid Mech., May, 1959, pp. 497-543. 20 refs. Study of a recent theory of homogeneous turbulence in which all statistical moments of the velocity field are derived analytically from the Navier-Stokes equation. The theory involves the average infinitesimal-impulse-response functions of the Fourier amplitudes and employs a new kind of perturbation method which yields what are believed to be exact expansions of third- and higher-order statistical moments of the Fourier amplitudes in terms of second-order moments and these response functions. An approximation of the theory is used to examine the energy dynamics and the spectral structure, with respect to both frequency and wave number, of the inertial and dissipation ranges of very high Reynolds Number stationary, isotropic turbulence. The energy spectrum is determined by a nonlinear integral equation, involving the time-correlation and response functions, which is suitable for solution by iteration. The theory is compared with other theories and experiments.

FLOW IN A VISCOUS TRAILING VORTEX. G. Newman. Aero. Quart., May, 1959, pp. 149-162. 13 refs. Presentation of a small perturbation analysis of a single trailing vortex. The equations of motion and continuity are linearized by assuming that both the rotational velocity and the deficit of longitudinal velocity within the vortex are small compared with the undisturbed stream velocity. As a result of the linearization, the equations for the rotational and longitudinal motion separate, and simple solutions are obtained for each. If the vortex is generated by a body with profile drag, the deficit of longitudinal velocity will be positive. Further details for the solution and its relation to the flow in real vortices are discussed, and the theory is compared with some measurements in a turbulent vortex.

Internal Flow

SINGULARITÄTENTHEORIE DER FLÜGELGITTER. I - DIE ACKERETSCHE GITTERTHEORIE. II - DAS STRÖMUNGSFELD BEI GEÄNDERTER ZUSTRÖMRICHTUNG. III - DAS RECHENSCHEMA FÜR DEN GITTERENTWURF. IV - GITTERENTWURF MIT PROGRAMMGESTEUERTEM RECHENAUTOMATEN. V - ENTWURF VON GITTERPROFILEN MIT VORGESCHRIEBENER FORM DER DRUCKVERTEILUNG AUF DER SAUGSEITE. VI - MESSUNGEN AN SCHAUFELGITTERN IM ELEKTROLYTISCHEN TROG. Ludwig Meyer. ETH Inst. für Aerodynamik, Mitteil. No. 26, 1959. 127 pp. 29 refs. In German. Development of a method of calculation for the design of two-dimensional cascades in incompressible flow. Experiments were made on the basis of electrolytic analogy. Includes derivation of Ackeret's cascade theory involving singularities; calculation of the flow field in the case of modified inflow direction; presentation of tables and diagrams used to determine the profile of cascade blades; calculation of pressure distribution in the case of shock-free inflow; description of numerical methods allowing for the calculation of the effect of various parameters on the profile shape and pressure distributions; and application of iteration methods to the design of cascade profiles with specified form of pressure distribution over the upper surface.

A CONTRIBUTION TO THE THEORY OF FLOW STABILITY IN MULTI-STAGE AXIAL COMPRESSORS. A. D. S. Carter. Aero. Quart., May, 1959, pp. 163-182. Study of the stability with respect to small changes in speed instead of mass flow. The finite rate of growth

of the circulation around each blade is examined. It is concluded that an instability occurs in the last stage of the compressor, even when that stage is itself unstalled, which could give rise to surge. The introduction of an empirical factor into the analysis is found necessary but, when given a value compatible with other experimental and theoretical evidence, reasonably good agreement with experimental results is obtained.

THE EFFECT OF AXIAL SPACING ON THE SURGE CHARACTERISTICS OF TWO MISMATCHED AXIAL COMPRESSOR STAGES. R. C. Turner. Gt. Brit., ARC CP 431, 1959. 29 pp. 11 refs. BIS, New York, $0.81. Investigation of two highly mismatched stages, tested at five interstage spacings over a wide range of flow coefficients. It was found that there was considerable mutual interference as regards the surge behavior, and the aerodynamic characteristics generally were also affected. In particular, at the lower spacings, the second stage considerably delayed the surge of the first.

FRICTION AND HEAT TRANSFER OF COMPRESSIBLE FLOW INTO AN INFINITE LATTICE OF FLAT PLATES. S. L. Soo. ZAMP, May 25, 1959, pp. 291-310. 15 refs. Analysis of an idealized system of an infinite lattice of flat plates of zero thickness. Two cases are considered: constant wall temperature (approximating the condition in a heat exchanger), and an adiabatic wall (approximating the condition of uncooled blade passages). The solutions of the equations are based on a Howarth transformation and a series expansion from the leading edge. Results are given in graphical form for friction drag, temperature distribution, and Nusselt Number.

Jet Flaps & Wings

POWER REQUIREMENT OF A BLOWING WING WITH SEALED AND SLOTTED TRAILING-EDGE FLAPS. H. B. Helmbold. Fairchild Aircraft & Missile Div. Eng. Rep. R246A-004, Mar. 13, 1959. 25 pp. ONR-supported experimental investigation of a blowing NACA 23015 airfoil with a sealed flap and an effective blowing-slot width of 0.7% chord, over a range of flap deflection angles from 0° to 70°. Only flows fully attached to the flap are considered. A comparison with the results for the slotted flap with wide blowing slot shows that, at high flap-deflection angles, the power requirement of the sealed flap is diminished only over a limited range of lift coefficients after reattachment, whereas for higher lift coefficients the slotted flap is definitely superior. Present results are discussed in their context with previous ones.

A THEORY OF THE JET FLAP IN THREE DIMENSIONS. E. C. Maskell and D. A. Spence. Royal Soc. (London) Proc., Ser. A, June 9, 1959, pp. 407-425. Extension of the treatment of two-dimensional jet-flapped wings to the case of a thin wing of finite aspect ratio having a deflected jet sheet of zero thickness emerging with a small angular deflection at its trailing edge. The downwash field is assumed to arise from elementary horseshoe vortices proportional in strength to the local lift distribution. The induced downwash $w_i(x, y)$ in the plane $z = 0$ at intermediate distances x from the wing cannot be calculated, and is therefore replaced by an interpolation formula. Two interpolation methods are discussed, they are chosen so as to allow the two-dimensional equation for loading to be used to calculate the loading in a streamwise section in three dimensions. The case is considered in which the loading and downwash distribution depend only on x/c, where x measures the distance from the leading edge and c(y) is the local chord. The relations between the coefficients of induced drag and lift, and between the lift coefficients in two and three dimensions are given. Results are compared with experimental measurements.

Performance

A QUANTITATIVE ANALYSIS OF THE CHARACTERISTICS AND LIMITATIONS OF AERODYNAMIC FLIGHT WITHIN THE ATMOSPHERE. I - CHARACTERISTICS. W. Ch. Walter. Aero/Space Engrg., Aug., 1959, pp. 43-46, 53. Presentation of the results of quantitative analysis of aerodynamic flight. The cruising vehicle flight regime and the aerospace vehicle flight regime are defined and analyzed, and the fundamental equations relating to these limits are derived. Design curves for use in preliminary design and performance estimates are presented. Although there is some overlap between the two flight regimes, each exhibits characteristics peculiar to the mode of operation taking place within their respective limits.

Stability & Control

THE STABILITY OF AN AIRCRAFT UNDER AUTOMATIC THROTTLE CONTROL AND THE CROSS COUPLING EFFECTS WITH ELEVATOR CONTROL. D. E. Fry and M. R. Watts. Gt. Brit., RAE TN I. A. P. 1079, Oct., 1958. 30 pp. Analysis showing that throttle application can be made proportional to change in airspeed, incidence, or rate of pitch to provide damping of a long periodic motion, but that speed is the most suitable variable. The control of an aircraft having negative static margin is considered and shown to require either the addition of an integral control on the throttle or a combination of throttle and elevator controls. Where it is required to control height by means of the elevator, some aircraft flying under certain conditions can only be adequately stabilized by means of an automatic throttle control.

EFFECT OF ARTIFICIAL PITCH DAMPING ON THE LONGITUDINAL AND ROLLING STABILITY OF AIRCRAFT WITH NEGATIVE STATIC MARGINS. M. T. Moul and L. W. Brown. US, NASA Memo. 5-5-59L, June, 1959. 25 pp.

XUM

Analysis of longitudinal and steady-rolling (inertial coupling) stability of a hypersonic glider configuration for center-of-gravity locations rearward of the aircraft neutral point. Results are presented for stability calculations and a simulator study assuming a velocity of 700 ft./sec. and an altitude of 40,000 ft. With no augmentation, the aircraft was rapidly divergent in the simulator study. When a pitch damper was employed as a stability augmenter, the short-period mode became overdamped, and the aircraft was easily controlled on the simulator. The analysis showed that the aircraft can be made free of rolling divergence for all roll rates with an appropriate damper gain.

INVESTIGATION OF THE STABILITY OF VERY FLAT SPINS AND ANALYSIS OF EFFECTS OF APPLYING VARIOUS MOMENTS UTILIZING THE THREE MOMENT EQUATIONS OF MOTION. Appendix A - DERIVATIONS OF EQUATIONS. Appendix B - EQUATIONS FOR MOTION OBTAINED WHEN VARIOUS FORCING FUNCTIONS ARE APPLIED IN ROLL. W. J. Klinar and W. D. Grantham. US, NASA Memo. 5-25-59L, June, 1959. 50 pp. Calculation of stability values for various rates of rotation and various magnitudes of the damping derivatives. It appears that contemporary designs will probably not have a stable spin when rolling-moment coefficients due to rolling or sideslip are required. Equations for applying various moments have been utilized and results show that the effect of moving ailerons with the spin or applying a positive pitching moment in producing recovery for contemporary fighter designs will be greatest for large negative values of yawing-moment coefficient due to sideslip.

Wings & Airfoils

TRANSONIC AERODYNAMIC CHARACTERISTICS OF TWO WEDGE AIRFOIL SECTIONS INCLUDING UNSTEADY FLOW STUDIES. P. J. Johnston. US, NASA Memo. 4-30-59L, June, 1959. 45 pp. 13 refs. Wind-tunnel investigation to determine the two-dimensional aerodynamic characteristics of a single 20%-thick wedge-airfoil section in the Mach Number range of 0.70 to 1.25. The results are compared with those of a diamond profile having the same leading-edge included angle. Pulsating pressure measurements are presented for the single wedge with leading-edge radii of 0, 0.5, and 1% of the chord. The single wedge produced normal-force curve slopes significantly higher than those previously measured on conventional thin airfoils.

AN EXPERIMENTAL STUDY OF THE FLOW FIELD ABOUT SWEPT AND DELTA WINGS WITH SHARP LEADING EDGES. Ivan Jaszlics and Leon Trilling. J. Aero/Space Sci., Aug., 1959, pp. 487-494, 544. 17 refs. AFOSR-supported investigation of low-speed flow field over high aspect ratio swept wing and narrow delta wings at high incidences. It is found that near the root section of either type of wing the flow is conical. The edge of the vortex sheet which originates at the leading edge is a straight line whose position relative to the leading edge depends only on incidence. On swept wings, the vortex edge turns downstream as soon as the vortex sheet covers the front half of the wing chord, and the flow under the vortex sheet outboard of that turning point is uniform and parallel to the leading edge of the wing. On narrow delta wings, the conical symmetry persists almost to the trailing edge.

THE AERODYNAMIC FORCES ON AN AEROFOIL IN UNSTEADY MOTION BETWEEN POROUS WALLS. S. Rosenblat. Quart. J. Mech. & Appl. Math., May, 1959, pp. 151-174. Derivation of the pressure on the airfoil surface in terms of the flow direction at the surface. The relations for the lift and moment about the mid-chord point are obtained for a harmonic upwash distribution. For the case of a rigid airfoil, particular types of harmonic oscillations are investigated, and the lift and moment are given as dimensionless "air-load" coefficients. The results are expressed as the first-order terms of expansions in powers of a parameter which depends on the ratio of airfoil chord to tunnel width, and are valid for small values of this ratio.

SUPERSONIC WIND TUNNEL TESTS OF RING-WING CONFIGURATIONS. L. H. Schindel. USAF WADC TR 58-220 [AD 155534], Dec., 1958. 103 pp. 29 refs. Presentation of measurements of aerodynamic forces and moments on ring-wing configurations. The main result indicates that the combination of linearized and slender body theory is not adequate to design a ring-wing vehicle so as to cancel the wave drag. Other tests provide data on tandem ring-wings and on the lifting effectiveness of support struts. In addition, some experimental results are reported on the area ratio required to start supersonic flow in the annular region between the wing and the body.

COEFFICIENTS AERODYNAMIQUES TRIDIMENSIONNELS QUASI STATIONNAIRES EN SUPERSONIQUE. G. Coupry. La Recherche Aéronautique, Mar.-Apr., 1959, pp. 49-56. In French. Development of a method for the calculation of three-dimensional, quasi-stationary aerodynamic coefficients. Simplifying assumptions are introduced and the applicability of the method to swept wings oscillating in supersonic flow is verified. The cases of rectangular and delta wings are also covered.

NOTE ON THE FORCES THAT ACT NEAR THE CENTRE AND THE TIPS OF A SWEPT-BACK WING. D. G. Hurley. Aero. Quart., May, 1959, pp. 127-144. Calculation of the drag near the tip of a semi-infinite swept-forward wing of constant chord at zero incidence to a uniform stream of incompressible, inviscid fluid, using the momentum equation. The drag is given as a function of wing section and angle of sweep and is shown to be unaffected by shaping the tip. The results may be used to calculate the drag

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near the center and the thrusts near the tips of a swept-back wing, provided that the aspect ratio is greater than two. Present and previous results are combined to estimate the spanwise extent of the forces. It is found that this extent decreases as the angle of sweep is increased and that it depends quite markedly on the wing section.

THEORETICAL STUDIES OF UNSTEADY TRANSONIC FLOW. IV - THE OSCILLATING RECTANGULAR WING WITH CONTROL SURFACE. M. T. Landahl. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 80, 1959. 28 pp. Presentation of a linearized solution for the transonic flow around a rectangular wing of arbitrary aspect ratio, calculated by a method of Schwarzschild. The solution is obtained as an infinite series in which the solution for a wing of infinite span constitutes the initial term. This series is shown to be convergent for all non-zero aspect ratios and reduced frequencies. Formulas are given and some numerical results presented for the spanwise distribution of forces and moments on rigidly oscillating rectangular wings and control surfaces. For total forces and moments very simple approximate formulas, valid for large aspect ratios, are given. It is shown that a control surface of high aspect ratio may have negative hinge-moment damping. However, for a control surface aspect ratio less than 3.5 the damping will be positive for all frequencies.

TABLES OF GENERALIZED AERODYNAMIC FORCES FOR TRIANGULAR WINGS WITH SUPERSONIC LEADING EDGES. Y. L. Luke and H. E. Fettis. USAF WADC TR 58-681 [AD 211654], Feb., 1959. 169 pp. Presentation of calculations performed on a computer using a series expansion developed previously. The key equations are also presented. It is assumed that modal descriptions of the triangular wings are available in the form of a double polynomial series in x and y, the chordwise and spanwise coordinates, respectively.

A THEORY OF THE FLOW PAST A SLENDER DELTA WING WITH LEADING EDGE SEPARATION. K. W. Mangler and J. H. B. Smith. Royal Soc. (London) Proc., Ser. A, May 26, 1959, pp. 200-217. 20 refs. Presentation of a potential flow model in which the vortex layer is replaced by a vortex sheet of spiral form. The problem is then reduced to a two-dimensional one by the use of slender-body theory and the assumption of a conical velocity field. The shape and the strength of the vortex sheet are found by using as boundary conditions two factors - the vortex sheet lies in a stream surface and there is no pressure difference across it. In practice, the inner and the outer parts of the spiral are treated separately. The inner part is regarded as small, and a solution is given for it, which is asymptotically correct as the center of the spiral is approached. The outer part is replaced by a sheet whose shape and strength depend on a finite number of parameters which are determined by applying the boundary conditions at isolated points. Results are given for the shape of the sheet and the pressures, loadings, and forces on the wing.

THEORETICAL STUDIES OF UNSTEADY TRANSONIC FLOW. V - SOLUTION FOR THE DELTA WING AND WINGS OF GENERAL POLYGONAL PLANFORMS. Appendix - CALCULATION OF THE NORMAL DERIVATIVE OUTSIDE THE WING EDGES. M. T. Landahl. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 81, 1959. 22 pp. 12 refs. Derivation of a solution for the unsteady transonic flow around a delta wing from that of a corresponding rectangular wing. The rectangular wing corresponding to a true delta wing has an infinite chord, but a finite chord for a delta wing with a cut-off apex. With the solution for this latter plan form as a basis, other solutions are constructed. In the approximate solution for a low-aspect-ratio triangular wing, the additional terms that result from jumps in the upwash distribution or its streamwise derivatives on the wing are calculated. The cut-off-delta solution is also used to build up the solution for general polygonal plan forms. For plan forms that are convex outwards the solution is obtained through a process of repeated lift-cancellations. For concave plan forms this process has to be supplemented by upwash-cancellations.

AUXILIARY TABLES FOR THE COMPUTATION OF LINEARIZED WING-BODY INTERFERENCE FLOWS. H. J. Stetter. Munich U. TN 6 (AFOSR TN 58-1089) [AD 207586], Nov. 10, 1958. 33 pp. Analysis covering the problem of the poor convergence of the Fourier series in the third step, shown previously in the quasi-cylindrical method for treating linear wing-body interference. It is shown that the solution may be composed of two parts such that the poorly convergent part is universal to all problems while the part distinguishing the various examples has a better convergence. Tables are presented for the universal portion of the solution of the third step giving the values of the flow component accounting for the local pressure coefficient in a large number of points on both wing and body.

AEROELASTICITY

DIVERGENCE OF PLATE AIRFOILS OF LOW ASPECT RATIO AT SUPERSONIC SPEEDS. G. J. Hancock. J. Aero/Space Sci., Aug., 1959, pp. 495-507, 517. Investigation of the divergence of low aspect ratio rectangular plate wings of constant thickness. It is assumed that the spanwise form of the structural distortion is known and that the aerodynamic forces are approximations of the supersonic linearized theory. The form of the chordwise distortion is deduced. The problem is also investigated using measured structural flexibility coefficients together with theoretical aerodynamic coefficients. The usual series solution based on the Rayleigh-Ritz approach is discussed using the previous assumptions. The results of these methods are consistent and indi-

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cate that the transonic regime at M = 1 is the most critical for divergence. It is shown that sweeping the leading edge of a plate airfoil of constant thickness increases its stability. For angles of sweep less than 30°, the critical conditions occur when the leading edge is sonic, but for angles greater than 30° the critical conditions occur when M = 1.

LA MATRICE D'AMORTISSEMENT STRUCTURAL DANS LES CALCULS DE FLOTTEMENT. P. Salaün. La Recherche Aéronautique, Mar.-Apr., 1959, pp. 43-48. In French. Study of a vibrating system with two degrees of freedom, coupled by viscous pseudo-damping and pseudo-elasticity and connected to an energy source. The equations of motion and the structural damping matrix are derived for the case of a wing-flap system, and the importance of structural damping in the calculation is emphasized.

INVESTIGATION OF THE RESPONSE TO RANDOM WIND GUSTS OF A TYPICAL SUBSONIC FIGHTER AIRCRAFT IN LEVEL FLIGHT WITH MACH NUMBER 0.9 AT SEA LEVEL. K. Flodin and M. Sundström. KTH Aero. TN 47, 1958. 25 pp. Computation of frequency spectra (power spectral densities) and root mean square deviations for all velocity components, attitude angles, components of displacement, and load factor for an aircraft in level flight subjected to normal atmospheric wind disturbances. The turbulence is defined by spectral density curves. The influence of different modifications as to the wind gust spectra is investigated for some of the outputs. Calculations are carried out under the assumption that the wind disturbance is the same all over the aircraft and that the spectrum of its velocity gradient is that given by Decaulne and Summers.

MECHANICS

SOME GENERAL CONCEPTS OF DYNAMICS AND THEIR APPLICATION TO THE RESTRICTED THREE-BODY PROBLEM. P. A. Lagerstrom and M. E. Graham. Douglas Rep. SM-23401, Dec., 1958. 125 pp. Review of kinematics emphasizing coordinate transformations. Conservation theorems and Lagrange's and Hamilton's equations of motion are discussed and illustrated. Integrals of motion for the two-body problem are found and with their aid the two-body problem is reduced to two uncoupled central-force problems. The general three-body problem is formulated and integrals of motion are found. Lagrange's special solutions are discussed. Finally, the restricted three-body problem is formulated under the assumption that two bodies of non-negligible mass each move in circles about their common center of gravity.

MISSILES, ROCKETS, SPACE CRAFT

VISTAS IN ASTRONAUTICS. I - SPACE ENVIRONMENT AND VACUUM RESEARCH. II - CONTROL AND PROPULSION OF VEHICLES OUTSIDE THE ATMOSPHERE. III - PANEL DISCUSSION. IV - DEPARTURE, SPACE NAVIGATION AND RE-ENTRY PROBLEMS. V - THE EARTH'S MOON. (2nd Annual Astron. Symposium, Denver, Apr. 28, 1958.) International Series of Monographs on Aeronautical Sciences and Space Flight, vol. II. Cosponsored by Air Force Office of Scientific Research and Institute of the Aeronautical Sciences. Edited by Morton Alperin and H. F. Gregory. London, New York, Pergamon Press, 1959. 318 pp. $15.00. Partial Contents: The Importance of High Vacuum in Space Environment Simulation, R. A. Roche. Scientific Uses of Cislunar Vehicles, S. F. Singer. Experimental Studies on Plasma Jet Propulsion, D. F. Howard. Some Considerations Pertaining to Space Navigation, Y. C. Lee and K. P. Conrad. The Utilization of a Satellite Laboratory for Life Science Studies, P. A. Campbell. The Launching of Space Vehicles by Air-Breathing Lifting Stages, A. Ferri, W. Daskin, L. Feldman, and L. M. Nucci. The Difference Between Satellite and Ballistic Missile Re-Entry Problems, F. R. Riddell and J. D. Teare. Comparative Performance of Ballistic and Low-Thrust Vehicles for Flight to Mars, J. H. Irving and E. K. Blum. Scientific and Engineering Exploration of the Moon, J. Barnes.

USE OF DRAG MODULATION TO REDUCE DECELERATION LOADS DURING ATMOSPHERIC ENTRY. R. L. Phillips and C. B. Cohen. ARS J., June, 1959, pp. 414-422. Analysis considering the problem of controlling vehicle trajectory in such a way that the peak deceleration load experienced by the vehicle is held to a tolerable maximum. This is accomplished by a variation in the drag of the vehicle by a variation of the ballistic parameter W/C_DA. The modulation may occur in a stepwise manner (such as dropping a flared skirt at a predetermined point in the trajectory) or may occur continuously, such as by programed flap deflection. The conditions which prevail when the vehicle enters the sensible atmosphere will dictate which method of W/C_DA variation is required. It is found that the use of continuous drag modulation can reduce deceleration loads by as much as 50%, without significantly affecting the total aerodynamic heating of the vehicle. In addition, the aerodynamic heating and landing point prediction problems are considered briefly.

PREDICTION THEORY OF MISSILE AND SATELLITE ORBITS. W. J. Berger and J. R. Ricupito. ARS J., June, 1959, pp. 428-432. Development of a minimal set of equations applicable to radio detection of an ICBM or reconnaissance satellite and preliminary prediction of its path and impact point. The input data, obtainable by modern radio tracking instrumentation systems, are assumed to consist of the position and velocity vectors of a "flying object" relative to a geodetic station. A necessary and sufficient condition is derived for deciding whether or not the object is moving in a gravitational orbit. Equations are then given for each case: for a sat-

ellite, the elements of the orbit and the time of visibility are found; for a missile, the geodetic coordinates of the impact point and the time of impact are computed; for an aircraft, geodetic coordinates of position are found.

INTERPLANETARY TRAVEL BY SOLAR SAIL. T. C. Tsu. ARS J., June, 1959, pp. 422-427. Study of a solar ship which has a mass ratio of unity, no power plant aboard, and no waste-heat disposal problem. The propulsive force, although small, can be applied continuously in a controlled direction. The ship has an infinite "propellant" reserve to correct errors of navigation, or to return to earth at any time. The equations of motion are solved, the sail tilt angle optimized, the time of travel computed, and the performance compared with that of chemical-rocket and ionic propulsion systems.

SYNTHESIS AND FLIGHT TEST OF A BALLISTIC MISSILE-ADAPTIVE FLIGHT CONTROL SYSTEM. O. B. Gates, Jr., and O. C. Kaste. IAS Natl. Summer Meeting, Los Angeles, June 16-19, 1959, Paper 59-124. 19 pp. Members, $0.50; nonmembers, $1.00. Presentation of the design philosophy employed in the synthesis and mechanization of a flight control system. Computed analog and digital responses of the roll and pitch loops are studied and, where possible, compared with the responses obtained from flight tests of the system over a wide range of atmospheric and aerodynamic environments. Correlation between theoretical and flight measured responses is excellent.

SIMULATION METHODS IN PROPORTIONAL NAVIGATION SYSTEMS FOR GUIDED MISSILES. Appendix I - DERIVATION OF THE ANGULAR VELOCITY COMPONENTS OF SIGHT-LINE AXES. Appendix II - MISSILE-EARTH AND EARTH-MISSILE AXIS TRANSFORMATION EQUATIONS. Appendix III - MISSILE-SIGHT LINE AND SIGHT LINE-MISSILE AXIS TRANSFORMATION EQUATIONS. Appendix IV - GIMBAL I AND II CONTROLS. N. E. Ives. Gt. Brit., RAE TN G.W. 502, Nov., 1958. 57 pp. Analysis of different methods for simulating the guidance and control systems requiring information about the angular velocity or spin of the sight-line. Also determined are the relative merits of the computation of the sight-line spin in terms of components along the x, y, and z axes of three different frames of reference, namely, earth axes, missile axes, and sight-line axes. It is shown that the spin components along the axes of any one of the different coordinate systems may be computed by utilizing either the relative acceleration, relative velocity, or relative position components of the missile-target system. It is found that each method of simulating the kinematic equations affects the amount of computing equipment required to simulate the remainder of the missile system. The advantages and disadvantages of computing the sight-line spin in terms of different systems of axes are given in tabular form.

EFFECT OF THRUST TERMINATION PROCESS UPON RANGE DISPERSION OF A BALLISTIC MISSILE. A. J. Kelly. ARS J., June, 1959, pp. 432, 437-440. Calculation of the range dispersion attributable to the nominal cutoff impulse acting on a variation in missile burnout mass as compared to a variation in cutoff impulse from the nominal value. The results are based upon reasonable estimates of engine and missile parameters. A generalized graph is presented which can be used to estimate the combined contribution of cutoff impulse deviation and burnout mass variation to the range dispersion once the nominal burnout conditions of the missile and engine are known. A numerical example of a hypothetical 500-nautical mile ballistic missile is presented.

OPTIMUM EXHAUST VELOCITY PROGRAMMING AND PROPULSION EFFICIENCY. Robert Fox. J. Astron. Sci., Spring, 1959, pp. 13-16. Analysis considering the variational problem of most efficient utilization of the fuel for the case of a rocket with separate fuel and energy sources which operates in field-free space. It is found that the exhaust velocity should be low (but not zero) initially and should rise during powered flight. This solution leads to a natural definition of propulsion efficiency for such a system which is invariant to choice of inertial reference frame. Some properties of the variational solution are discussed briefly.

SOME ASPECTS OF A THREE-BODY PROBLEM. G. K. Oertel and S. F. Singer. U. Md. Phys. Dept. Rep. (AFOSR TN 59-405) [AD 214502], Mar., 1959. 21 pp. Analysis of the motion of a particle in the field of two nonrotating mass centers whose separation remains fixed. Applying a formalism developed by Charlier, limits for the motion of this small mass are derived, and the equations for the ellipses are given in terms of the constants of motion. Simple expressions for a particular choice of initial conditions are obtained. The equations of the two limiting ellipses are shown to depend only on the separation of the two centers of attraction and not on the mass distribution between them. For the case in which the two limiting ellipses coincide, the energy and the equation of the orbit are independent of the total mass between the two centers. The applicability of the theory to problems of celestial mechanics is considered.

CONTROLLED RECOVERY OF NON-LIFTING SATELLITES. R. W. Detra, F. R. Riddell, and P. H. Rose. Avco Res. Lab. RR 54, May, 1959. 18 pp. Discussion considering the problem of recovering, at a preselected site, satellites that are orbiting close to the earth. Considerations are limited to vehicles which accomplish re-entry into the atmosphere with drag devices. Two possible means of effecting controlled recovery of satellites are considered: (a) recovery accomplished by a single perturbation of the satellite orbit as may be done with a single solid-fuel retrograde rocket; (b) recovery accomplished by

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continuous application of a small force of controllable magnitude. This could be done with a low-thrust controllable rocket motor or, if the satellite is orbiting in the outer fringes of the atmosphere, by varying the drag area of the vehicle. These two cases may be considered as extremes in the way in which the perturbing forces can be applied. The "intermediate" case of a controlled recovery by a series of impulsive forces (e.g., by a number of small retrorockets) is not considered.

POWER PLANTS

PROPULSION THROUGH HEATING AT SUPERSONIC SPEED. K. Oswatitsch. (DVL Bericht 90, Apr., 1959.) Gt. Brit., RAE Lib. Transl. 811, Mar., 1959. 19 pp. Discussion of a propulsion method that employs heating of the trailing edge of an airfoil at high Mach Numbers. Compatibility conditions for the general case are given after the introduction of streamlines and their orthogonal trajectories as coordinates. Heating of profiles at supersonic speed in front of their maximum cross section leads to an increased drag. Propulsion results at subsonic speed if heating occurs at the front or rear point of stagnation. Heating at the maximum cross section also creates drag.

ANALYTICAL INVESTIGATION OF THE EFFECT OF TURBOPUMP DESIGN ON GROSS-WEIGHT CHARACTERISTICS OF A HYDROGEN-PROPELLED NUCLEAR ROCKET. H. E. Rohlik and J. E. Crouse. US, NASA Memo. 5-12-59E, June, 1959. 37 pp. Study of axial-flow, mixed-flow, and centrifugal pumps driven by single- and twin-turbine drive systems for application in a high-pressure bleed-type turbopump unit. The effects of turbopump weight and turbine flow rate required for each type are shown in terms of the ratio of rocket gross weight to payload for a fixed mission.

Jet & Turbine

APPLICATION DE METHODES DE VISUALISATION A L'ETUDE DE FOYERS DE REACTEURS. C. Fouré. La Recherche Aéronautique, Mar.-Apr., 1959, pp. 21-26. In French. Application of two visualization techniques to the study of jet engine combustion chambers. The need for controlled distribution of the injected fuel for some combustion conditions, particularly those requiring a stoichiometric mixture, is emphasized. The experimental procedure is described in detail, and it is shown that the results are sufficiently satisfactory to serve as the basis for a simplified method of calculation in combustion research.

Rocket

ANALYSIS OF A SIMPLIFIED MODEL OF SOLID PROPELLANT RESONANT BURNING. W. Nachbar and L. Green, Jr. J. Aero/Space Sci., Aug., 1959, pp. 518-526. AFOSR-supported study of a proposed model describing resonant burning of solid propellants. It is shown that if a certain "critical" frequency is present in the frequency spectrum of gas phase oscillations in the combustion chamber, oscillations will occur in the heat input to the propellant surface which, in turn, couple with the decomposition mechanism to cause a change in the mean burning rate. The obtained results permit calculation of this critical frequency as a function of the propellant parameters and the steady-state burning conditions.

ROCKET THRUST TERMINATION TRANSIENTS. Appendix I - REFERENCE TIME AND IMPULSE INCREMENTS. Appendix II - RESPONSE TO A STEP INPUT. H. C. Rodean. ARS J., June, 1959, pp. 406-409. Derivation of equations showing the nature of thrust decay, the impulse increment of the thrust termination transient, and the time constant of the transient. The equations are developed for two idealized cases involving simplifying assumptions and the results are plotted in generalized form. The first case is a fixed nozzle area ratio with zero ambient pressure, and the second case is the variable nozzle area ratio and finite ambient pressure. The analysis is considered to hold for liquid propellant rockets with instantaneous propellant shutoff and "sliverless" burnout of solid propellant rockets.

ANALYSIS OF FLOW-SYSTEM STARTING DYNAMICS OF TURBOPUMP-FED LIQUID-PROPELLANT ROCKET. R. P. Krebs and C. E. Hart. US, NASA Memo. 4-21-59E, Apr., 1959. 45 pp. Analysis concerning the flow dynamics involved in rapidly increasing the flow from a value just sufficient to maintain combustion to a value corresponding to that required for full thrust. Two rocket configurations are considered. In one configuration the inlet pressure to the turbine was fixed at the design value, while the second configuration employed a "bootstrap" technique for supplying energy to the turbine. From the analysis two parameters were developed from which the speed response time of the turbopump, the flow response time, and the maximum dynamic line loss could be evaluated. These parameters were functions of turbopump moment of inertia, design performance of the turbine, and flow-system geometry. The moment of inertia of the turbopump and the ratio of turbine torque at zero speed to design torque had the largest influence on the starting dynamics of the flow system.

RESEARCH, RESEARCH FACILITIES

Wind Tunnels

GASDYNAMICS OF A WAVE SUPERHEATER FACILITY FOR HYPERSONIC RESEARCH AND DEVELOPMENT. Appendix A - SIMULATION CAPABILITIES OF THE WAVE SUPERHEATER WITH RESPECT TO HEAT TRANSFER PHENOMENA ON BALLISTIC MISSILES. R. C. Weatherston, A. L. Russo, W. E. Smith, and P. V. Marrone. Appendix B - SIMULATION CAPABILITIES OF THE WAVE SUPERHEATER WITH

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RESPECT TO IONIZATION PHENOMENA ON BALLISTIC MISSILES. A. H. Flax. Cornell Aero. Lab. Rep. AD-1118-A-1 (AFOSR TN 59-107) [AD 210223], Feb., 1959. 133 pp. 34 refs. Discussion of the fundamental gas-dynamic and heat-transfer aspects of a wave superheater designed to generate 9,000°R. in uncontaminated air. The superheater utilizes preheated helium driver and preheated test gases and can superheat 4.3 lbs. of uncontaminated air per sec. at 200 atmos. stagnation pressure. Argon can be readily substituted for air as a test gas and superheated to 17,000°R. at the rate of 12 lbs./sec. Cooling of the superheated structure and the effects of heat transfer within the superheated air are examined in detail. Certain shock tube experiments were performed to test the nonsteady heat transfer theory in the range of interest.

FLASH X-RAY RADIOGRAPHY FOR THE DENSITY MEASUREMENT IN A HYPERSONIC AIR FLOW. Fumio Tamaki and Chul-Soo Kim. Phys. Soc. Japan J., May, 1959, pp. 664-669. 12 refs. Development of a soft X-ray radiographic method using a flash X-ray tube, and application to the measurement of the density distribution between a circular cylinder and the detached shock wave at a free-stream Mach Number of 5.5 and a free-stream density of about one-tenth of the normal atmosphere. Results indicate the suitability of the method for investigating hypersonic flow fields, especially for measuring narrow regions with steep density gradients, because the effect of refraction can be neglected without error in the wavelength range of X-rays.

OPERATION AND PERFORMANCE OF A SHOCK TUBE WITH HEATED DRIVER. R. C. Evans. GALCIT HRP Memo. 48, Feb. 1, 1959. 29 pp. Army-sponsored discussion of the design and evaluation of a method to directly heat the gas in a shock tube driver, in order to increase the shock Mach Number. This is accomplished by means of electrical heating elements (Calrods) installed inside the driver. The temperature rise increased the shock wave number by about 40%, or from values of 7.7 to 10 for pressure ratios of 20,000 across the diaphragm. This increase is sufficient to produce partial dissociation of the oxygen molecules behind the shock wave. A transition section was designed to enable the major portion of the low pressure chamber to be constructed of round Shelby tubing, while the test section still had a flat top and a flat bottom.

ROTATING WING AIRCRAFT, HELICOPTERS

THE COMPUTED INSTANTANEOUS VELOCITIES INDUCED AT THE BLADE AXES BY THE SKEWED HELICAL VORTICES IN THE WAKE OF A LIFTING ROTOR IN FORWARD FLIGHT. Walter Castles, Jr., and H. L. Durham, Jr. GIT Rep. [AD 210613], Mar., 1959. 117 pp. ONR-supported presentation of values of the instantaneous normal velocity component in the form of graphs and tables. The results were obtained by numerically approximating the normal component of the general Biot-Savart integral. Examples are given illustrating the use of the tabulated data to approximate the effects of a finite number of blades and finite rotor angular velocity upon the induced power and also upon the incremental blade loading along the blade radii. The examples indicate the significance of these effects.

FLIGHT INVESTIGATION OF EFFECTS OF TRANSITION, LANDING APPROACHES, PARTIAL-POWER VERTICAL DESCENTS, AND DROOP-STOP POUNDING ON THE BENDING AND TORSIONAL MOMENTS ENCOUNTERED BY A HELICOPTER ROTOR BLADE. L. H. Ludi. US, NASA Memo. 5-7-59L, May, 1959. 38 pp. Test results indicating that partial-power vertical descents and landing approaches produce rotor-blade moments that are higher than the moments encountered in any other flight condition investigated to date with this equipment. Deceleration through the transition region in level flight was found to result in higher vibratory moments than acceleration through this region. Deliberately induced static droop-stop pounding produced flapwise bending moments which where as high as the moments experienced in landing approaches and partial-power vertical descents.

STRUCTURES

Beams & Columns

THE EFFECTS OF INELASTIC ACTION ON THE RESISTANCE TO VARIOUS TYPES OF LOADS OF DUCTILE MEMBERS MADE FROM VARIOUS CLASSES OF METALS. VIII - ECCENTRICALLY-LOADED TENSION MEMBERS MADE OF TWO STAINLESS STEELS TESTED AT ELEVATED TEMPERATURES. O. M. Sidebottom, M. E. Clark, and S. Dharmarajan. IX - T-SECTION ECCENTRICALLY-LOADED TENSION MEMBERS MADE OF TYPE 304 STAINLESS STEEL AND TESTED AT 1000°F. O. M. Sidebottom and S. Dharmarajan. USAF WADC TR 56-330, Pts. VIII, IX [AD 202495; AD 202496], Oct., 1958. 53; 12 pp. VIII - Investigation to determine the load necessary to produce a specified amount of inelastic deformation in rectangular-section members made of type 304 and 17-7PH stainless steel. Two different theories are used. In one theory each isochronous stress-strain diagram is represented by two straight lines, and the load and deflection of the eccentrically loaded members were obtained from interaction curves and moment-load curves. In the other theory each isochronous stress-strain diagram is represented by a hyperbolic sine curve. It is found that the load and/or deflection could be adequately represented by either theory, with the latter giving better results. IX - Application of the interaction curve-moment-load curve theory to predict the load and deformation of the eccentrically loaded members. Comparison between theory and experiment was excellent for those members with sufficiently small initial eccentricity that yielding did not occur in the most stressed compression fibers. For those members with

larger eccentricity, the experimental moment-load curves fell appreciably below the theoretical curve over the range of the curve for which yielding had occurred on the compression side of the member. It is believed that this discrepancy results from the fact that the yield stress in compression is less than in tension.

Cylinders & Shells

THE EDGE EFFECT IN SYMMETRIC BENDING OF SHALLOW SHELLS OF REVOLUTION. Eric Reissner. Commun. on Pure & Appl. Math., May, 1959, pp. 385-398. ONR-supported analysis of the edge effects for shallow shells of revolution and generally symmetric load distributions with both a simply supported edge and a built-in edge. It is shown that for certain well-defined ranges of parameter values the boundary layer at the edge of the shell is such that within one boundary layer of specified width there is to be found a second boundary layer, the width of which is of a different order of magnitude. The wider of the two edge zones is associated with nonlinear membrane action and the narrower zone is associated with nonlinear bending action.

THERMAL STRESSES IN SHELLS OF REVOLUTION OF VARIABLE ELASTIC PROPERTIES. Chao Hwei-Yuan. Scientia Sinica, Apr., 1959, pp. 383-400. Analysis of thermal stresses due to axisymmetric and steady-state temperature gradient in shells of revolution. It is assumed that the shell material possesses temperature-dependent elastic properties such that Young's modulus is a linear function of temperature and Poisson's ratio is constant. The values of stresses and couples for variable elasticity are small in comparison with the values calculated in the case of constant elastic modulus, and the tendency of the variations becomes smooth. The relative ratio of the decrement of the maximum absolute values of stresses and couples has the same order as the relative ratio of the decrement of Young's modulus. Consequently, the influence of the variable elasticity due to temperature can not be neglected in the case of high-temperature gradient.

THE ANALYSIS OF FUSELAGES OF ARBITRARY CROSS-SECTION AND TAPER. IV. J. H. Argyris and S. Kelsey. Aircraft Eng., June, 1959, pp. 169-180. Presentation of stress systems for the fuselage with a double-cell cross section allowing for the direct stress carrying ability of the floor. Wing-fuselage interaction redundancies are discussed in detail and suitable self-equilibrating load systems presented. A brief account is given of fin attachment loads, which serves to introduce two further interaction redundancies to take account of skin attachment. Detailed frame loads are presented for the overall fuselage loading, preparatory to the analysis of the closed frames. Matrix equations for the calculation of the statically equivalent wing reactions and of the fuselage moment diagrams are given.

Elasticity & Plasticity

THE PROPAGATION OF PLANE IRROTATIONAL WAVES THROUGH AN ELASTOPLASTIC MEDIUM. L. W. Morland. Royal Soc. (London) Philos. Trans., Ser. A, June 11, 1959, pp. 341-383. 20 refs. Analysis of wave propagation in a metal, treating interactions between elastic and plastic waves and the formation and propagation of shock waves, in the general case of motions with unidirectional strain arising from an initial smooth loading-unloading pulse. A stress-strain relation with linear elastic paths and concave-upward plastic paths is derived and used so that the elastic wave velocity is uniform, and the plastic wave velocity an increasing function of stress. Analytic solutions to the interactions between different types of continuous waves are developed incorporating an expression for the motion of the elastic-plastic boundary. The breakdown of a smooth plastic compression wave into a shock wave is presented, and the propagation conditions are derived.

NICHT-LINEARE ELASTIZITÄTSTHEORIE DER VERSETZUNGEN UND EIGENSPANNUNGEN. Ekkehart Krŏner and Alfred Seeger. Arch. Rational Mech. & Anal., Apr. 20, 1959, pp. 98-119. 33 refs. In German. Presentation of two approaches for the development of the nonlinear theory of elasticity covering dislocations and natural stresses in solid bodies. The analysis is based on theories derived by Kondo, Bullough, Bilby, and Smith. Examples illustrating the distribution of dislocations are given and specific stress fields in an infinite isotropic medium are calculated. The discussion shows that the stress equations used in the linear theory are also applicable to the case of the quadratic theory, in particular, to problems involving Airy's stress functions. The theory can also be used in the study of thermal and magnetostrictive stress problems.

Fatigue

ESTIMATION OF AIRCRAFT FATIGUE LIFE. E. Aubrey and B. Venkatraman. Can. Aero. J., June, 1959, pp. 207-214. Presentation of a simplified and rapid method of calculating the life expectancy of an aircraft. Using the analyses of Chilver and Harper as bases, a relatively simple formula is derived for the damage per mile. The fundamental assumptions made in estimating fatigue damage are discussed, and equations for estimating aircraft fatigue life are presented. Direct reading charts for damage per mile and altitude corrections are given and their use is illustrated by calculating the fatigue of a typical aircraft.

Plates

ON THE BUCKLING OF CERTAIN OPTIMUM PLATE STRUCTURES WITH LINEARLY VARYING THICKNESS. E. H. Mansfield. Aero. Quart., May, 1959, pp. 145-148. Theoretical determina-

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tion of the buckling stress under uniform longitudinal compression. It is shown that for given cross-sectional area and overall dimensions the sections with linearly varying thickness achieve a greater buckling load (assuming that local buckling, rather than Euler buckling, is the criterion) than sections with any other smooth variation of thickness. These particular sections are therefore optimum and can be used as a yardstick for comparison purposes. The buckling loads are considerably greater than those for the corresponding "constant thickness" sections.

Plates with Holes

ASYMMETRICALLY PLATE-REINFORCED CIRCULAR HOLE IN A UNIFORMLY END-LOADED FLAT PLATE. Raymond Hicks. Aero. Quart., May, 1959, pp. 183-198. 12 refs. Derivation of general expressions for the stress distribution in a flat plate. The reinforcement of the hole is placed on one side of the plate only so that the other side remains flush. It is shown that the effect of an asymmetrically placed reinforcement is to induce, in the plate and reinforcement, bending stresses which are not negligible compared with the externally applied direct stress. Particular examples indicate that reinforcements having practical dimensions can give rise to stress concentrations in the same order of magnitude as those in a similarly loaded plate containing the unreinforced hole. Data are obtained enabling the rapid determination of stress distributions associated with reinforcements and plates having a reasonably wide range of dimensions.

Wings

AN APPROXIMATION TO THE INFLUENCE FUNCTION FOR PLATE-LIKE WINGS. R. D. Milne. Aircraft Eng., June, 1959, pp. 156-162. 16 refs. Presentation of a general solution in the form of an influence function for small deflections of thin plates of slowly varying thickness under lateral loading. It is shown that the influence function may be represented as an infinite series in terms of the eigenfunctions and eigenvalues associated with a homogeneous form of the plate differential equation. A numerical example is given for a uniform cantilever plate and the results are compared with experiment and with similar results deduced by an alternative theoretical procedure.

INVESTIGATION OF THE STRUCTURAL BEHAVIOR AND MAXIMUM BENDING STRENGTH OF SIX MULTIWEB BEAMS WITH THREE TYPES OF WEBS. J. P. Peterson and W. E. Bruce, Jr. US, NASA Memo. 5-3-59L, May, 1959. 28 pp. 12 refs. Results of bending tests on beams of nearly optimum weight-strength design having a ratio of beam depth to compression-cover thickness of 40. It is concluded that existing methods of analysis were adequate for predicting structural behavior, local buckling, and failure of the beams. Built-up multiweb test beams with an angle connector between the web and the compression cover were just as efficient as test beams with a tee-cap connector in resisting local buckling or failure.

THERMODYNAMICS

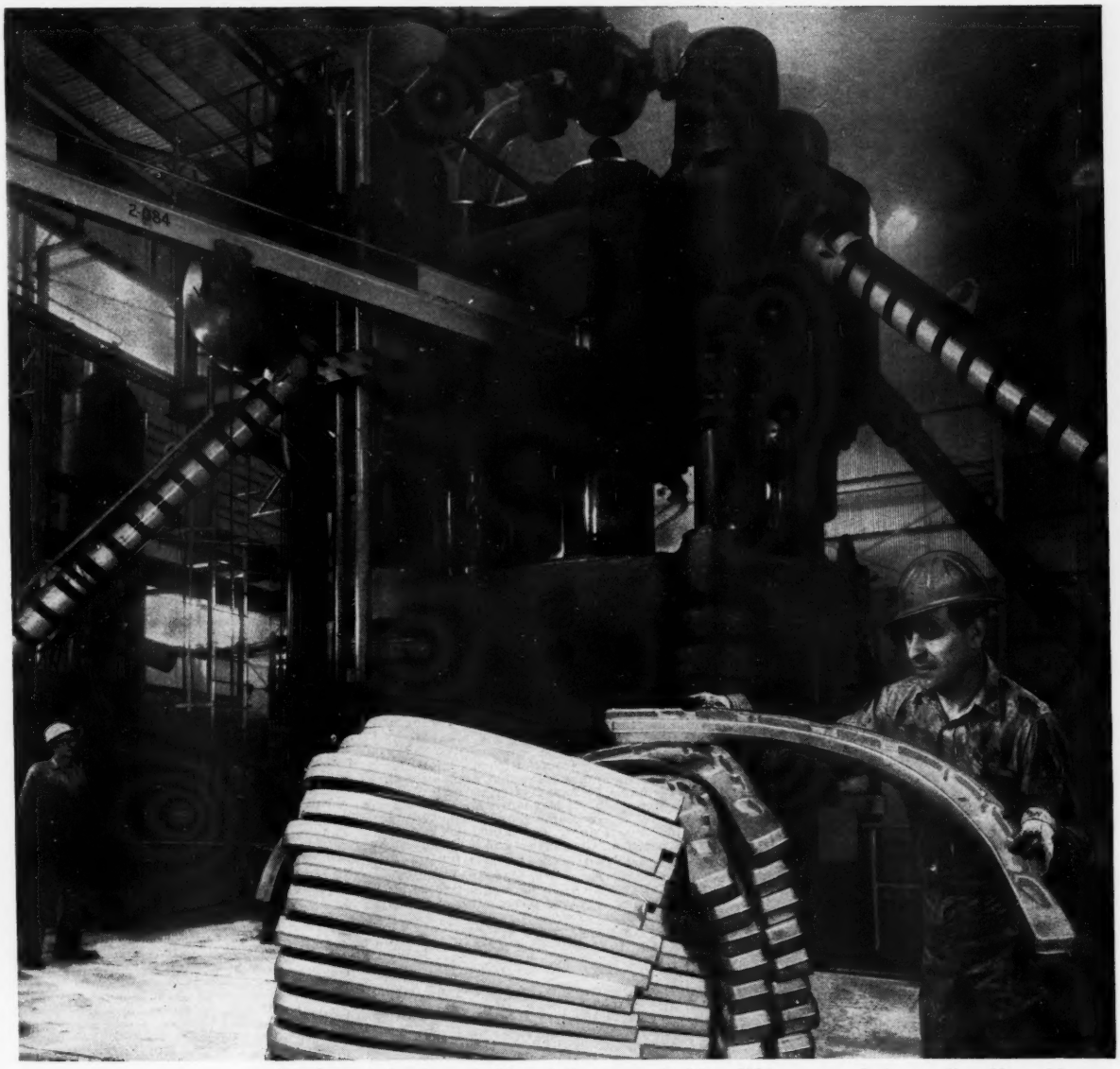
Combustion

DETERMINATION OF ACTIVATION ENERGY AND REACTION ORDER IN PREMIXED LAMINAR FLAMES. A. Van Tiggelen, P. J. Slootmaekers, S. De Jaegere, and H. Vandenabeele. Louvain U. Lab. Inorganic Chem. TSR (AFOSR TR 59-36) [AD 213039], Feb., 1959. 64 pp. 56 refs. Discussion of the theoretical basis for the determination of the activation energy and the reaction order with respect to fuel and oxidant from experimental data on burning velocities. Measurements of flame propagation, temperature, and flame front thickness in $N_2H_4/O_2/A$ are reported and compared with data on N_2H_4 decomposition flames. A general formula for the burning velocity of N_2H_4 mixtures is given. Flame propagation velocities are presented for fluorine mixtures with H_2, CO, and CH_4. Flame temperatures are calculated and used for the determination of activation energies in these flames, and a comparison with H_2/Cl_2 flames is made. A comparative study of flame propagation in nitrocompound mixtures is made, and preliminary results of the influence of preheating on burning velocities are given.

SPRAY COMBUSTION THEORY. F. A. Williams. Comb. & Flame, June, 1959, pp. 215-228. OOR-supported derivation of coupled steady-state equations of motion for a statistical ensemble of spherical droplets and a coexisting multicomponent reacting gaseous continuum, under the assumption that the induced random fluctuations in the properties of the fluid are negligible. These equations are reduced to a form appropriate for describing the one-dimensional flow of a fluid containing a spray which is stationary with respect to the gas. The burning-rate eigenvalue problem for one-dimensional heterogeneous combustion processes of the type $A \longrightarrow nB$ is formulated, and an analysis for sprays composed of uniform droplets illustrates the properties of the eigenvalue.

VTOL & STOL

A THEORETICAL APPROACH TO THE CONVERSION STAGE OF TILTING ROTOR CONVERTIPLANES. P. F. Sutherby. Aircraft Eng., June, 1959, pp. 163-168. Calculation of the state of a tilting rotor convertiplane during the conversion from hovering to forward flight, and the effect on this state of changes in some of the aircraft design variables. Equations are deduced and solutions presented in terms of values for the rotor angle α and the induced velocity v_i. From these values the effective wing incidence β, the thrust required per unit wing area, and power required per unit wing area are derived. The effects of these values on design parameters is then studied. The results suggest that the design of a convertiplane will present considerable aerodynamic problems.



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Metals & Alloys

Presente y Futuro de los Materiales Metalicos Aeronauticos. J. A. G. Poggio. (*Assoc. Aero. Engr. Gen. Meeting, Madrid, Nov. 31, 1958.*) *Ing. Aero.*, Nov.-Dec., 1958 pp. 1–19. 30 refs. In Spanish. Survey covering various materials used in the construction of aircraft and power plants; present and future requirements, taking into account the properties of various materials, and the future of metallurgy in the field of high temperature.

On Stress Interaction in Fatigue and a Cumulative Damage Rule. A. M. Freudenthal and R. A. Heller. (*USAF WADC TR 58-69*, June, 1958.) *J. Aero/Space Sci.*, July, 1959, pp. 431–442. 17 refs.

Breves Consideraciones Sobre el Desgaste. E. J. G. Sardinero. *Ing. Aero.*, Nov.-Dec., 1958, pp. 35–43. In Spanish. Discussion of the wear encountered in mechanisms, considering in particular internal combustion engines. Included are such aspects as erosion, cavitation, surface temperature, lubricant properties, and atmospheric conditions.

Fretting in the Light of Aircraft Experience. P. B. Walker. *RAeS J.*, May, 1959, pp. 293–298. Discussion of the mechanism of fatigue initiation by fretting and presentation of some methods for the prevention of fretting.

How to Get the Most from Sheet Metal in High Temperature Service. H. A. Pearl. *Materials in Des. Eng.*, May, 1959, pp. 116–120. Discussion of design efficiency of materials and types of structures for extended use in a high-temperature and oxidative environment. Multi-web beams, unstiffened cylinders, and thin foils are considered.

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The Effect of Metallurgical Variables on the Fatigue Properties of AISI 4340 Steel Heat Treated in the Tensile Strength Range 260,000–310,000 psi. J. I. Fisher and J. P. Sheehan. *USAF WADC TR 58-289 [AD 208321]*, Feb., 1959. 144 pp.

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The Low-Temperature Mechanical Properties of Some Cast Stainless Steels. G. Mayer and K. Balajiva. *Metallurgia*, May, 1959, pp. 221–226. Presentation of tensile and impact properties of steels at temperatures between 100°C. and −196°C.

Metals & Alloys, Nonferrous

Development of Wrought Beryllium Alloys of Improved Properties. I. J. G. Klein, L. M. Perelman, and W. W. Beaver. *USAF WADC TR 58-478, Pt. I [AD 208663]*, Feb., 1959. 139 pp. 48 refs.

Influenţa Tratamentului Termic in Condiţii Naturale Asupra Frecărilor Interne ale Nichelului Deformat Plastic. A. Cişman, B. Rothenstein, and J. Hrianca. *Stud. Cerc. Ştiint., Ser. Ştiint. Teh.*, Jan.-June, 1958, pp. 47–55. 12 refs. In Rumanian, with summaries in Russian and German. Experimental study of the effect of heat-treatment on the internal friction of plastically deformed nickel.

Ob Izmeneniiakh Sil Mezhatomnoi Sviazi v Odnofaznom Tverdom Rastvore Nikel'-Aliuminii. G. V. Kurdinkov, V. K. Kritskaia, P. A. Lataiko, and Iu. A. Osip'ian. *AN SSSR Dokl.*, Jan. 1, 1959, pp. 76–78. In Russian. Study of the variation of interatomic bonding forces in a single-phase solid nickel-aluminum solution.

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O Dlitel'noi Prochnosti Nekotorykh Deformirovannykh Materialov pri ikh Korroziionnom Rastreskivanii. Iu. S. Zuev and A. Z. Borshchevskaia. *AN SSSR Dokl.*, Jan. 21, 1959, pp. 613–616. 20 refs. In Russian. Description of tests on rubber materials subjected to deformation in order to study the static strength in the presence of corrosion cracking.

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A Literature Survey of Theories and Methods of Predicting Characteristics of Materials. E. E. Underwood, M. F. Amateau, R. E. Maringer, and G. K. Manning. *Battelle Memorial Inst., Columbus, Ohio, Rep. (USAF MDC TR 59-1) [AD 154109]*, Jan., 1959. 207 pp. 1,784 refs.

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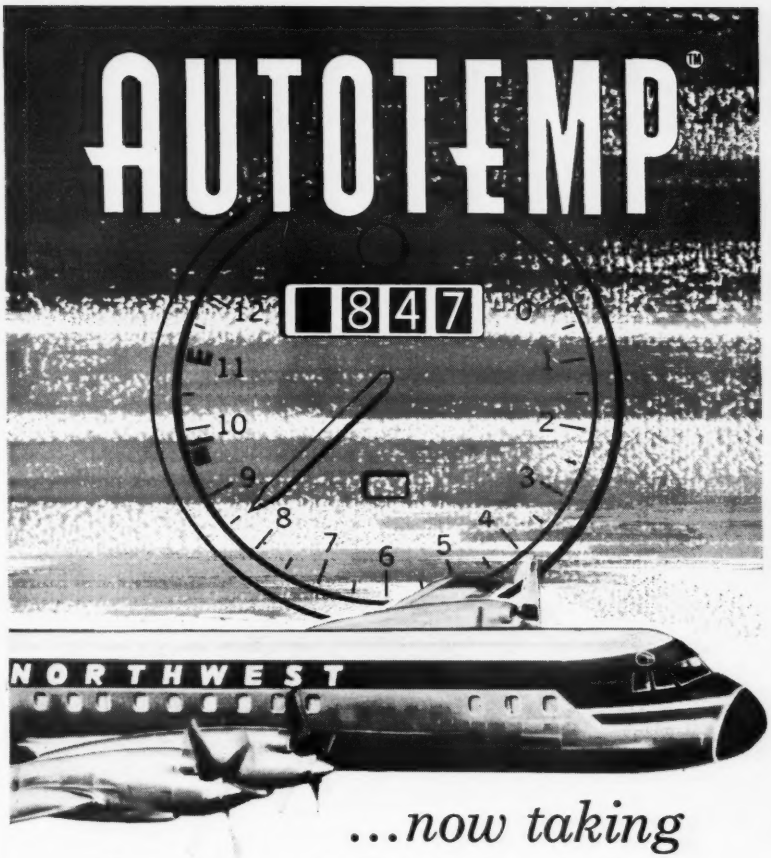

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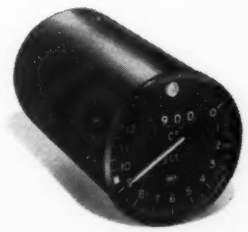

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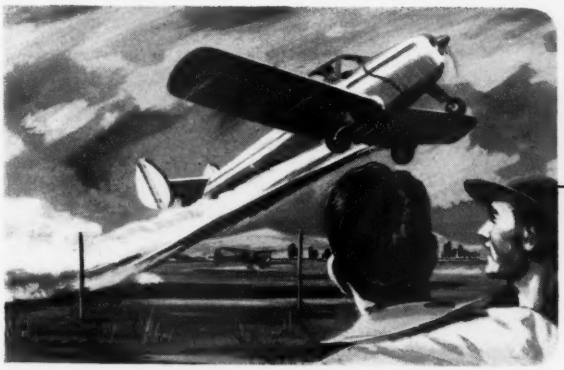

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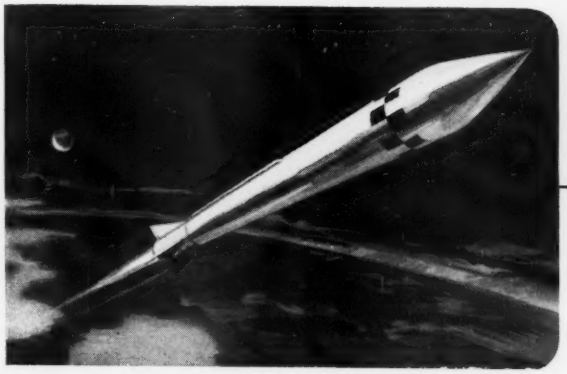

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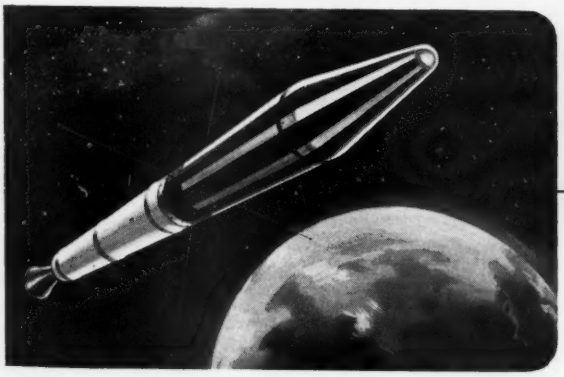

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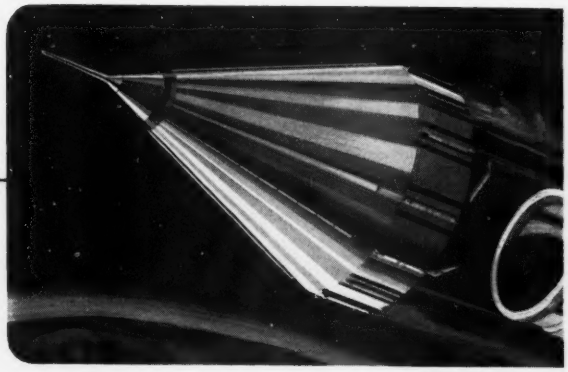

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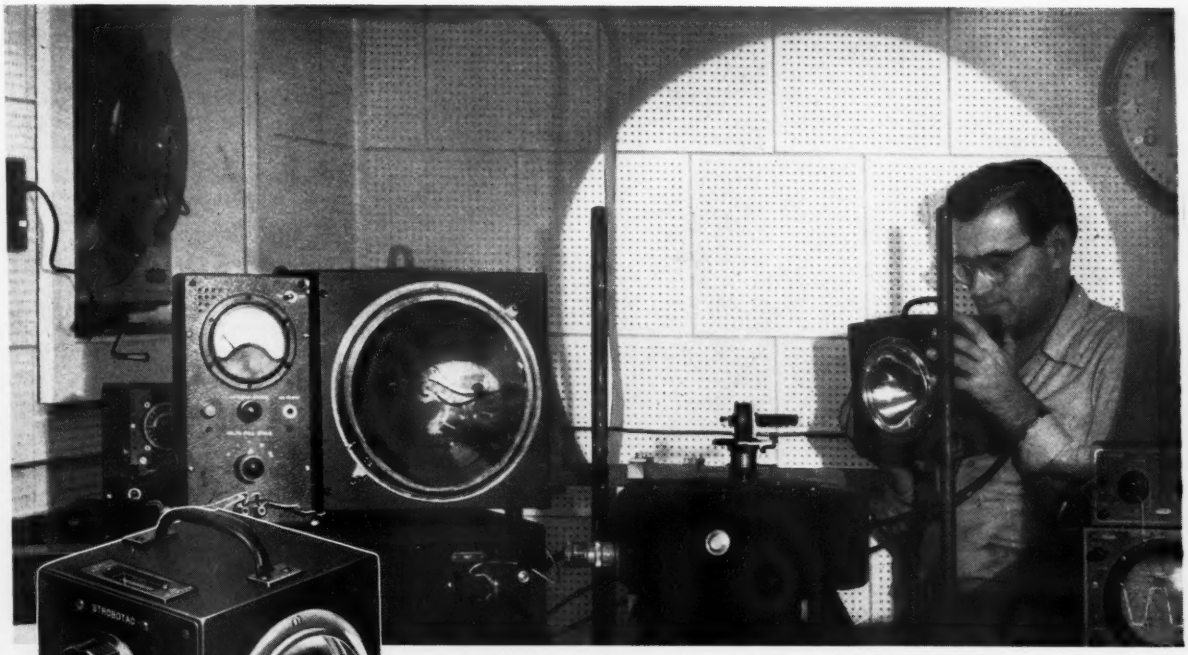

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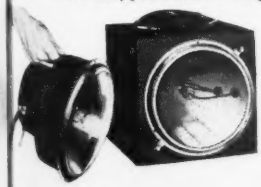

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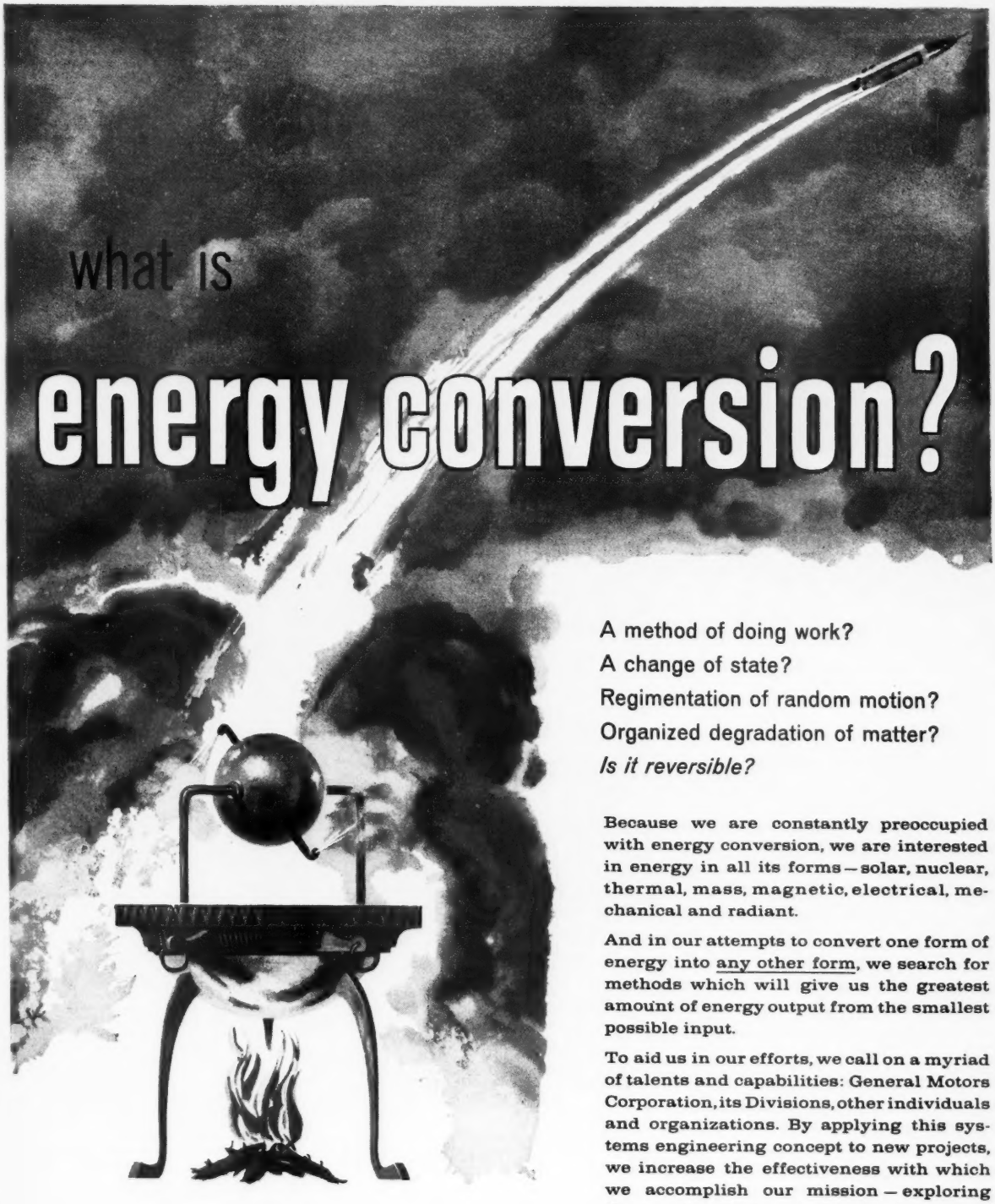

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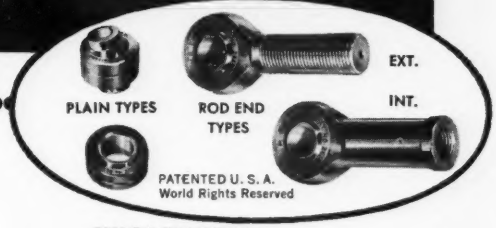

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The Stability of Thin-Walled Cylinders Under Combined Torsion and External Lateral or Hydrostatic Pressure. H. S. Suer and L. A. Harris. *ASME Trans., Ser. E - AM*, Mar., 1959, pp. 138–140. Application of Donnell's eighth order differential equation to determine theoretical buckling coefficients. An experimental investigation was conducted to verify the calculations.

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Limit Analysis of Symmetrically Loaded Thin Shells of Revolution. D. C. Drucker and R. T. Shield. (*ASME Annual Meeting, New York, Nov. 30-Dec. 5, 1958, Paper 58-A-26.*) *ASME Trans., Ser. E - AM*, Mar., 1959, pp. 61–68. ONR-sponsored analysis showing the yield surface for a thin cylindrical shell to be a very good approximation to the yield surface for any symmetrically loaded thin shell of revolution. Hexagonal prism approximations to this yield surface, appropriate for pressure vessel analysis, are described and discussed in terms of limit analysis.

On Influence Coefficients and Nonlinearity for Thin Shells of Revolution. Eric Reissner. (*ASME Annual Meeting, New York, Nov. 30-*

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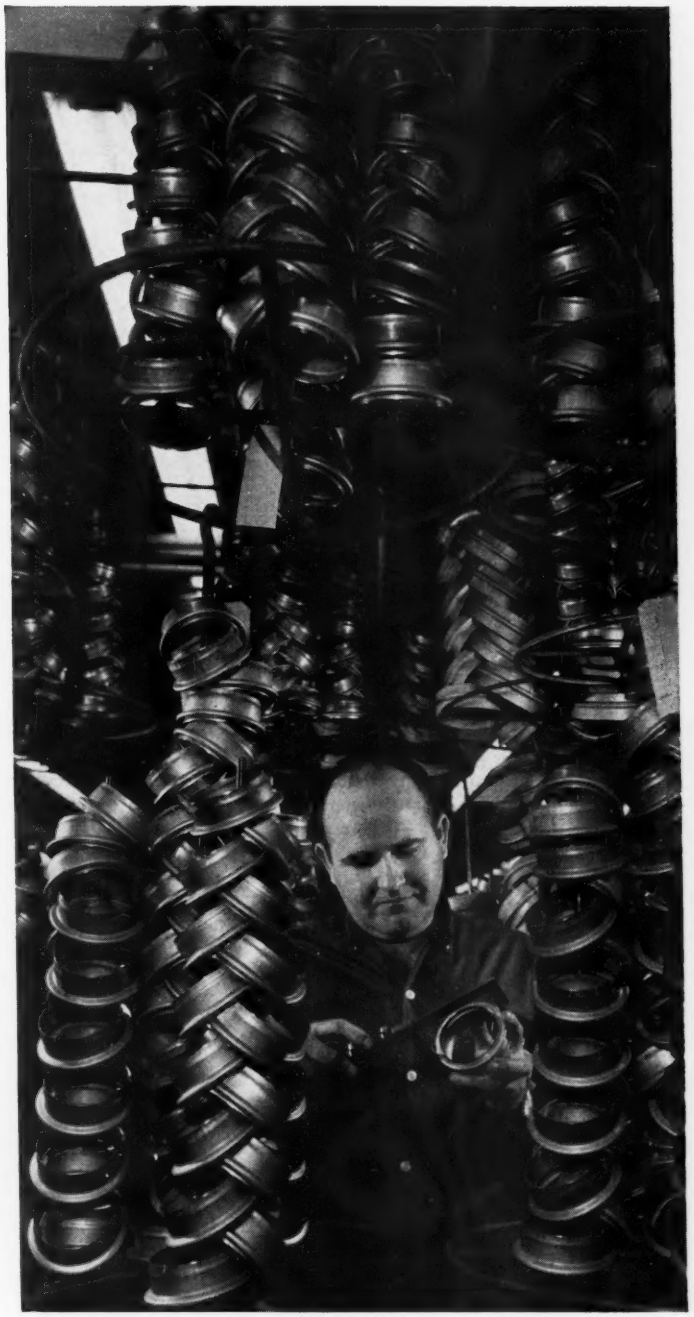

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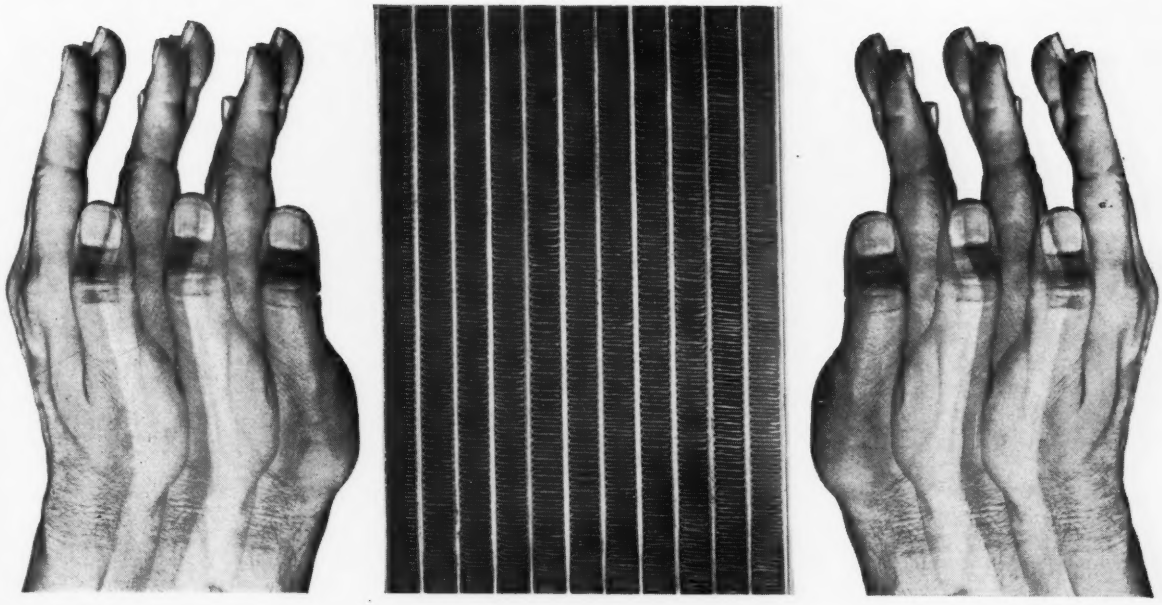

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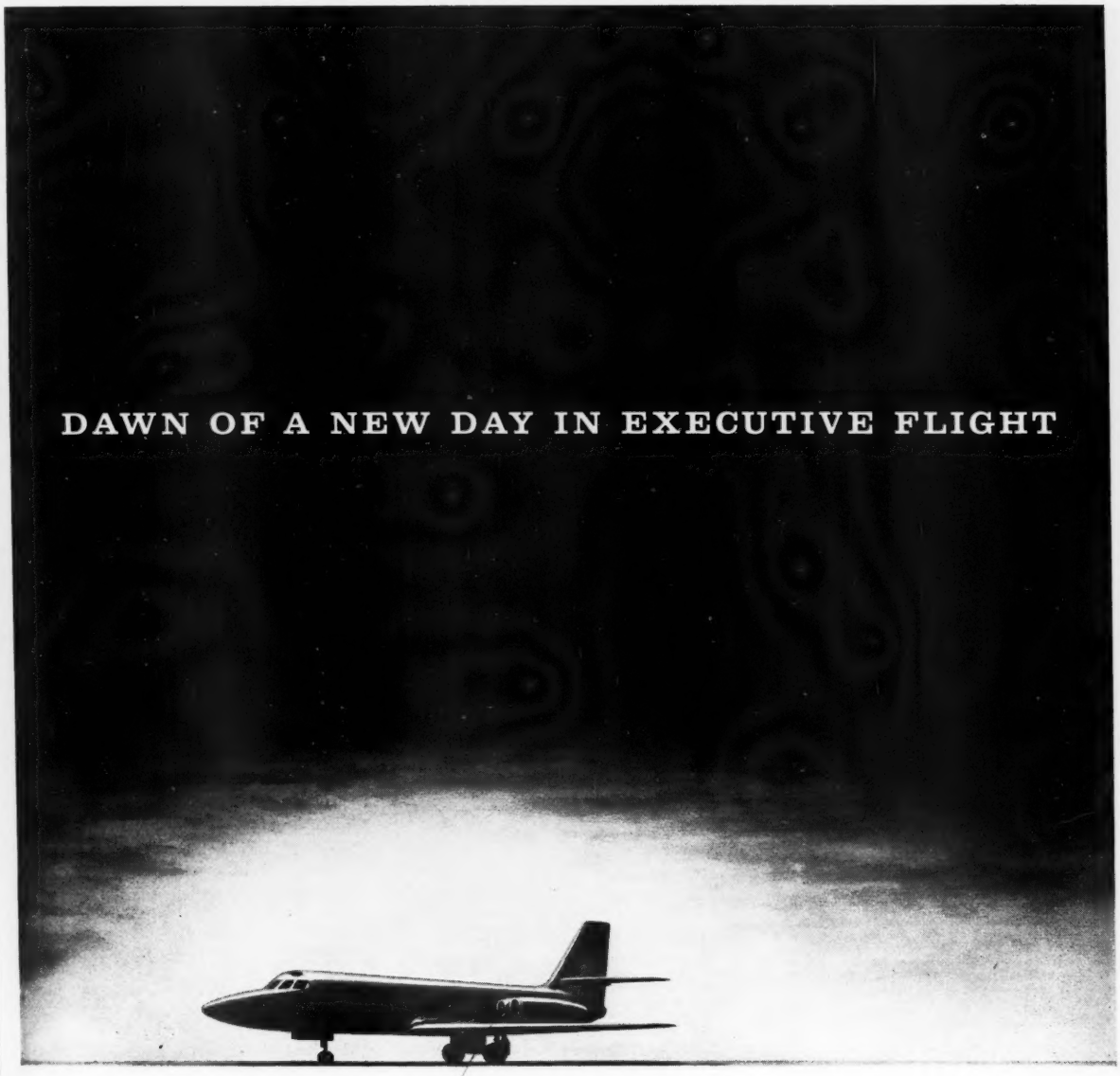

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On the Uniqueness of the Solutions of the Equation of Weak Convection in the Steady State. M. M. Farzetdinov. (*Prikl. Mat. i Mekh.*, Mar.-Apr., 1958, pp. 286–288.) *PMM—Appl. Math. & Mech.*, No. 2, 1958, pp. 393–397. Translation.

Generalized Solution for the Problem of Pipe Flow with Friction and Heat Addition. R. W. McJones and M. L. Caplan. *ARS J.*, May, 1959, pp. 366–368.

Numerical and Machine Solutions of Transient Heat-Conduction Problems Involving Melting or Freezing. I—Method of Analysis and Sample Solutions. W. D. Murray and Fred Landis. (*ASME-AIChE Heat Transfer Conf., Chicago, Aug. 18–21, 1958, Paper 58–HT–16.*) *ASME Trans., Ser. C - HT*, May, 1959, pp. 106–112. 29 refs.

The Mechanism of Thermal-Gradient Mass Transfer in the Sodium Hydroxide-Nickel System. Appendix A—Existence of Sodium Nickelite in Sodium Hydroxide—Nickel System. Appendix B—The Effect of Hydrogen Upon Mass Transfer and Nickelite Concentration. Appendix C—Rate of Formation of Sodium Nickelite. Appendix D—Reactions of Chromium and Its Compounds with Molten Sodium Hydroxide. Appendix E—Chromate-Chromite Equilibrium in Molten Sodium Hydroxide. Appendix F—Equilibrium Concentration of Sodium Oxide in Sodium Hydroxide. Appendix G—Corrosion and Mass Transfer in Sodium Hydroxide-Copper System. Appendix H—Thermoelectric Potential of Nickel in Molten Sodium Hydroxide. Ch. E. May. *U.S., NACA Rep. 1366*, 1958. 20 pp. 15 refs. Supt. of Doc., Wash., $0.25.

Heat and Mass Transfer from a Rotating Disk. F. Kreith, J. H. Taylor, and J. P. Chong. (*ASME-AIChE Heat Transfer Conf., Chicago, Aug. 18–21, 1958.*) *ASME Trans., Ser. C - HT*, May, 1959, pp. 95–103; Discussion, pp. 103–105. 33 refs. Application of the analogy between heat, mass, and momentum transfer to a rotating disc. Experimentally measured mass-transfer rates from a disc rotating in an infinite environment under laminar and turbulent conditions are related to the corresponding heat-transfer process.

A Theory of Rotating Condensation. E. M. Sparrow and J. L. Gregg. (*ASME Annual Meeting, New York, Nov. 30-Dec. 5, 1958, Paper 58–A-70.*) *ASME Trans., Ser. C - HT*, May, 1959, pp. 113–120. Analysis of film condensation on a rotating disc situated in a large body of pure saturated vapor. The problem is formulated as an exact solution of the complete Navier-Stokes and energy equations. Numerical solutions are obtained for Prandtl Numbers between 0.003 and 100.

Rapid Calculations for Boundary-Layer Transfer Using Wedge Solutions and Asymptotic Expansions. H. J. Merk. *J. Fluid Mech.*, Apr., 1959, pp. 460–480. 40 refs. Evaluation of the Meksyn wedge method and description of a modification for calculating local heat-transfer numbers. A method is also shown for asymptotic expansions that provide convenient relations which are capable of expressing the Nusselt Number explicitly in terms of the Prandtl Number.

Eine Methode zur Berechnung quasistationärer Temperaturzustände bei gesteuerten Wärmeleitvorgängen in festen Körpern. Hans Jäckel. *ZAMP*, Mar. 25, 1959, pp. 133–142. In German. Presentation of a method for the calculation of quasistationary temperature conditions by controlled heat-conduction processes in solid bodies. The problem treated by Vodička is solved as an example.

Heat Transfer in Liquid Metals. P. S. Lykoudis and Y. S. Touloukian. (*ASME-AIChE Heat Transfer Conf., University Park, Pa., Aug. 11–15, 1957, Paper 57–HT–16.*) *ASME Trans.*, Apr., 1958, pp. 653–663; Discussion, pp. 663–666. 28 refs. Study of heat transfer of liquid metals for the case of a fully developed turbulent flow in cylindrical pipes of constant diameter, the fluid under consideration being heated or cooled by a constant and uniform heat input at the wall.

Dynamic Response of Heat Exchangers Having Internal Heat Sources. V. S. Arpaci and J. A. Clark. *USAF WADC TR 57-483 [AD 155807]*, Dec., 1957. 35 pp. 20 refs. Presentation of a theoretical solution for the transient response of wall and fluid temperatures in a heat exchanger, including some experimental data. Excellent agreement exists between analytical and experimental results.

Dynamic Response of Heat Exchangers Having Internal Heat Sources. I, II. J. A. Clark, V. S. Arpaci, and K. M. Treadwell. (*ASME Annual Meeting, San Francisco, June 9–13, 1957, Paper 57–SA-14.*) *ASME Trans.*, Apr., 1958, pp. 612–634. 48 refs.

VTOL & STOL

Ground Proximity: A Critical Review. G. B. Matthews and J. L. Wosser. *IAS Natl. Summer Meeting, Los Angeles, June 16–19, 1959, Paper 59–121.* Members, $0.50; nonmembers, $1.00. 19 pp. 17 refs. Discussion of possible applications of "ground effect" vehicles and of their practicality. Various plan forms and schemes for lift augmentation in operations close to the ground are analyzed.

Entwicklungsstand der Steil- und Lotrechtstarter. R. W. Schulz. *Luftfahrttechnik*, Jan. 15, 1959, pp. 5–11. In German. Survey of the development of VTOL and STOL aircraft, including technical features of various classes and description of individual aircraft.

Wind-Tunnel Tests of Shrouded Propellers and Their Application. R. K. Wattson, Jr., and V. O. Hoehne. (*IAS Natl. Summer Meeting, Los Angeles, June 16–19, 1959, Paper 59-107.*) *Aero/Space Engrg.*, July, 1959, pp. 58–62. Abridged. Army-Navy-sponsored description of the test program and discussion of regime of operation to be considered for the shrouded propeller. It is concluded that if the requirements include vertical take-off and a maximum speed that is not too high, the shrouded propeller properly utilized may successfully compete either with the free propeller–engine combination or with the turbojet.

Lotrechtstart und Stabilisierung. G. Ernst. *Luftfahrttechnik*, Jan. 15, 1959, pp. 17–21. In German. Discussion covering the stability of VTO aircraft, considered in connection with safety, and means of stabilization. Results of tests on the flying ATAR are used as illustrative examples.

Das Lotrechtstart-Versuchsflugzeug C 450 der S.N.E.C.M.A. Gerhard Richter. *Luftfahrttechnik*, Jan. 15, 1959, pp. 12–17. In German. Description of the SNECMA experimental VTOL aircraft, type C 450, covering the control cabin, propulsion unit, circular wing, tail unit, jet control and stabilization, control systems, and safety arrangements.

Pionierarbeit der SNECMA auf dem Gebiet des Senkrechtstarts und der Senkrechtlandung. *Flugwelt*, Jan., 1959, pp. 12–14. In German. Discussion of the development achieved by SNECMA in the field of VTOL and STOL aircraft.

Design Philosophy and Test Experiences of a VTOL Aircraft. B. J. Uberti and J. B. Reichert. *IAS Natl. Summer Meeting, Los Angeles, June 16–19, 1959, Paper 59–122.* Members, $0.50; nonmembers, $1.00. 11 pp. Description of the aircraft (a tilt-wing, ducted fan configuration), the ground test program, test apparatus, and the instrumentation. The flight test program is outlined and preliminary results are presented.

What Price VTOL? M. O. McKinney, Jr. *Space/Aeronautics*, May, 1959, pp. 46–48. Discussion of the feasibility of future VTOL transports. Comparisons are made between unloaded-rotor, propeller-powered, and jet-powered VTOL aircraft and conventional transports.

The Army is Getting Flying Platforms. *SAE J.*, Apr., 1959, pp. 40–44. Design considerations for three different vehicles. General requirements, and stability and control problems are considered.

Another Fairey Record; Rotodyne is World's Fastest Rotorcraft. *Fairey Rev.*, Mar., 1959, pp. 2–6.

Water-Based Aircraft

Hydrodynamic Impact. V. G. Szebehely. *Appl. Mech. Rev.*, May, 1959, pp. 297–300. 49 refs. Review of work on the water entry problem. The subject is defined and current applications are listed along with current theories and applicable physical principles.

Exploratory Study of Ventilated Flows About Yawed Surface-Piercing Struts. J. P. Breslin and Richard Skalak. *U.S., NASA Memo. 2-23-59W*, Apr., 1959. 65 pp. Investigation of the phenomenon of atmosphere-connected cavities about surface-piercing struts. Conditions for the existence of such ventilated flows which have been derived from the experimental data are presented.

IAS News

(Continued from page 24)

causes serious delays in air traffic clearances?

Mr. Quesada: The FAA hopes to develop the radar surveillance net to the point where it will be possible to do away with the airways.

Q: What is the FAA doing to encourage feeder airlines since the trend is to get rid of all old equipment and to put jet transport operation away from cities?

Mr. Quesada: The FAA promotes aviation, but the success of feeder airlines would depend on their own efficiency. They will have to become efficient enough to encourage people to use them so that they no longer need subsidy. The FAA is studying the patterns of present traffic, and results of these studies might be a traffic structure which would serve the country by establishing centers of high-density traffic which the feeder lines could serve. New types of aircraft should be brought into the feeder line operation which the FAA does encourage.

Q: How does the FAA plan to control the segments of air traffic—i.e., the military and civil airlines, and the business and private pilots?

Mr. Quesada: All of these elements of aviation will be given the opportunity to perform in accordance with the standards and rules established by the FAA. All pilots will be treated alike. Depending on the type of flight operation, all will be required to fly in accordance with the rules so that they will not operate in such a manner as to become a hazard to the public.

Q: What is being done to reduce the travel time between the airport and the community inasmuch as flying time from Los Angeles to Washington, D.C., might become less than time required to get from Chantilly to Silver Springs?

Mr. Quesada: In general, the airport is the responsibility of the community and it must be developed by the community since the community benefits by the service obtained from the airport. The Government should not develop airports but standards of safety.

William Littlewood, President of the IAS and Vice-President of American Airlines, acted as Honorary Chairman for the evening. Cliff Laechelin represented Convair as the sponsor for the meeting's social hour.

Distinguished guests included J. Pyle, Deputy Administrator, FAA; J. W. Crowley, Director, Aeronautical and Space Research, NASA: Capt. A. C. Packard, USN, Acting Director, Bureau of Research & Development, FAA; and Gen. Orval Cook, President, Aerospace Industries Association.

QUENTIN J. GOSS, *Secretary*

Publications abstracted may be borrowed from the IAS Library. In making inquiry, please mention the month of *Aero/Space Engineering* in which the abstract appeared. This will facilitate servicing of requests.

REVIEWS OF *Books*

. . . in the field of aeronautical engineering and space technology

AERODYNAMICS, FLUID MECHANICS

Hypersonic Flow Theory. Wallace D. Hayes and Ronald F. Probstein. (Applied Mathematics and Mechanics, Vol. 5.) New York, Academic Press, Inc., 1959. 464 pp., diagrs., tables. $11.50.

This book, which serves as a vehicle for unpublished, original work of the authors, is directed to students and research workers in the field of modern gas dynamics and to hypersonic aerodynamicists, although specific material on the dynamics of hypersonic flight or hypersonic wing theory has been excluded from the text. Some of the material included, of course, is directly pertinent to these subjects. The authors have generally taken the point of view of classical fluid mechanics and have not delved deeply into the field of high-temperature gas dynamics, nor have they included any magnetohydrodynamic theory or any developments involving treatment of the Boltzmann equation.

The first five chapters, which were written by Professor Hayes, cover general features of hypersonic flow fields, small-disturbance theory, Newtonian theory, constant-density solutions, and the theory of thin shock layers. The concluding five chapters by Professor Probstein concern themselves with other methods for blunt-body and locally supersonic flows, viscous flows and viscous interactions, and free molecule and rarefied gas flows.

The requisite mathematical background is about what is needed for most compressible flow theory—primarily a knowledge of partial differential equations and vector analysis. The last three sections of Chapter 3 involve the concepts of dyadics or tensors. In general, the reader will find an ability to appreciate approximations and their limitations most helpful.

Professor Hayes is associated with Princeton University and Space Technology Laboratories; Professor Probstein is with Brown University and Avco Research Laboratory.

1959 Heat Transfer and Fluid Mechanics Institute: Held at University of California, Los Angeles, Calif., June 11–13, 1959. Preprints of Papers. Stanford, Calif., Stanford University Press, 1959. 243 pp., illus., diagrs., tables. $7.50.

Contents: (1) A New Analytic Representation of Surface Interaction for Hyperthermal Free-Molecule Flow with Application to Satellite Drag, R. Shamberg. (2) Local Heat Transfer, Recovery Factor, Pressure Distribution Around a Circular Cylinder Normal to a Rarefied Supersonic Air Stream, O. K. Tewfik and W. H. Giedt. (3) The Structure of a Steady Magnetohydrodynamic Switch-On Wave, Z. O. Bleviss. (4) The Flow of an Electrically Conducting Fluid Through a Duct with Transverse Magnetic Field, C. C. Chang and T. S. Lundgren. (5) The Magnetohydrodynamics of a Layer of Fluid Having a Free Surface, C. DuP. Donaldson. (6) The Suppression of Turbulence in Pipe Flow of Mercury by an Axial Magnetic Field, S. Globe. (7) Turbulent Skin Friction at High Mach Numbers and Reynolds Numbers, F. W. Matting, D. R. Chapman, J. R. Nyholm, and A. G. Thomas. (8) Heat Transfer on Blunt Nosed Bodies in General Three-Dimensional Hypersonic Flow, R. Vaglio-Laurin. (9) Stagnation Point Heat Transfer in a Partially Ionized Gas, R. W. Rutowski. (10) Energy Transfer in the Couette Flow of a Radiant and Chemically Reacting Gas, R. and M. Goulard. (11) Heat Transfer in Laminar Separated and Wake Flow Regions, W. O. Carlson. (12) Mass Transfer Cooling in a Steady Laminar Boundary Layer Near the Stagnation Point, A. A. Hayday. (13) On Ablation for the Recovery of Satellites, S. Georgiev, H. Hidalgo, and M. C. Adams. (14) Vaporization of a Refractory Oxide During Hypersonic Flight, S. M. Scala. (15) Diffusion in Neutral and Ionized Gases with Extreme Pressure Gradients, J. L. Kerrebrock. (16) High Temperature Gas Mixtures for Simulating Air and Other Planetary Atmospheres, K. E. Tempelmeyer. (17) The Decaying Plasma as a Method of Heating a Supersonic Gas Stream, J. C. Williams, III. (18) Experiments on a Radio Frequency Discharge Plasma in Supersonic Flow, R. L. Chuan and F. O. Smetana.

AERONAUTICS, GENERAL

Aviation Facts and Figures, 1959. Edited by Ben S. Lee. Washington, American Aviation Publications, Inc., 1959. 147 pp., diagrs., tables. $2.00.

Contents: Production and Facilities. Military Aviation. Guided Missiles. Space Program. Research and Development. Manpower. Finance. General Aviation. Helicopters. Airlines and Transportation. Aviation Export and Foreign Aviation. Public Relations Officials, AIA. Sources. Index.

AIR TRANSPORTATION

Air Transport Facts and Figures. 20th Ed. Washington, Air Transport Association of America, 1959. 31 pp., diagrs., tables.

CONTROL THEORY

Feedback Control Systems; Analysis, Synthesis, and Design. J-C Gille, M. J. Pélegrin, and P. Decaulne. New York, McGraw-Hill Book Co., Inc., 1959. 793 pp., diagrs., tables, charts. $16.50.

The aim of this book, which is intended as a servomechanism textbook for graduate students and as a reference book for engineers working in the automatic control field, is to provide in a single place a treatment of the overall theory of feedback control systems and of their components. The work corresponds to lectures and problems given since 1950 at the École Nationale Supérieure de l'Aéronautique, Paris, and since 1956 at the Faculté des Sciences, Laval University, Quebec. For those who would use the book as a text, the subject matter can be divided into two categories: (1) material constituting a consistent textbook in the basic theory of servomechanisms and (2) additional data on more advanced methods.

A distinguishing quality of the work is that the philosophy and technique of presentation are European rather than American. More than average attention is given to the pure and applied mathematics underwriting modern automatic-control theory and to the physical limitations of their use. It provides a presentation of contemporary American technology, but, more importantly, it provides a comprehensive English-language version of contemporary European and Russian work in both the linear and nonlinear areas. In keeping with this approach, the authors, who are all French scientist-engineers, have furnished the reader with an extensive selected bibliography which lists many European references and with a useful five-language glossary of automatic control terms with lucid notes explaining Russian and German concepts.

The book has already been translated into three European languages—German, Russian, and Polish.

CRYOGENICS

Experimental Techniques in Low-Temperature Physics. Guy Kendall White. London, New York, Oxford University Press, 1959. 328 pp., illus., diagrs., tables. 45*s*. $7.20.

The aim of this book is to provide those physicists, physical chemists, metallurgists, and engineers who are becoming interested in the investigation of materials at low temperatures with some of the information they may need to carry out their investigations. It deals specifically with the production and measurement of low temperatures, the handling of liquefied gases on the laboratory scale, the principles and some details of the design of experimental cryostats including the problems of heat transfer and temperature control, and physical data on heat capacities, expansion coefficients, and electrical and thermal conductivities of solids used in making low-temperature equipment. While it contains many references to technical details, a sufficient discussion of fundamental principles is included to make it useful to the advanced university student or graduate student.

Contents: (1) Production of Low Temperatures. (2) Storage and Transfer of Liquefied Gases. (3) Heat Exchangers. (4) Temperature Measurement. (5) Introduction to Cryostat Design. (6) Heat Transfer. (7) Temperature Control. (8) Adiabatic Demagnetization. (9) Vacuum Techniques and Materials. (10) Heat Capacity and Expansion Coefficient. (11) Electrical and Thermal Resistivity. Author Index. Subject Index.

DIRECTORIES

Interavia ABC, World Directory of Aviation and Astronautics. 1959, 7th Ed. Geneva, Interavia, 1959. 1409 pp., illus., diagrs. $12.

Compiled in five languages—English, French, German, Italian, and Spanish—this edition, revised for the most part to March 1, 1959, on international aeronautics and astronautics contains 34,000 listings of administrations, organizations, companies, and enterprises, together with 38,000 addresses and names of individuals. The four main sections consist of (1) The Alphabet, listing the world's civil and military aviation authorities and organizations, air lines, aircraft and equipment manufacturers, missiles and electronics firms, aero clubs, and other types of aeronautical activity; (2) the Analyt, which provides telephone numbers, addresses, names of management personnel, products, air-line fleets, and other data on the organizations and firms listed in the Alphabet section; (3) the Indicator, a five-language glossary of about 1,000 aeronautical items, each of which is cross-referenced to the appropriate Analyt section, thus also forming a Buyer's Guide; and (4) Who Is Where, an alphabetic list of aviation personalities, officers, and executives.

ELECTRONICS

Proceedings of the National Electronics Conference, Chicago, October 13–15, 1958. Vol. 14. Chicago, National Electronics Conference, Inc., 1959. 1079 pp., illus., diagrs., tables. $7.50.

Partial Contents: Space or Electronics—Which Will Dominate the Century?, S. Ramo. Transistor—Magnetic Pulse Generator, A. Krinitz. Transistor-Diode Logic R. A. Carlsen. An Approximation to Simplify the Analysis of Closed-Loop Sampled-Data Systems with Non-Negligible Pulse Width, G. J. Murphy. Transient Response of a Servomechanism with Backlash, J. B. Kreer and G. H. Fett. Vacuum Tubes and Transistor Circuits in Control Systems, D. P. Brown and J. J. Lang. On a Compromise Approach to Servomechanism Dynamics Response Optimization, C. L. Smith and C. T. Leondes. Surface-Wave Dielectric-Disc Antenna, R. E. Niebuhr and E. H. Schiebe. A Radio Astronomy System, G. Doundoulakis. The Electro-Acoustic Transducer and its Application to Sonar Systems, G. Rand and J. Devine. Principles of Inertial Navigation, W. Wrigley, W. R. Markey, and J. Hovorka. Doppler Radar Navigation, F. B. Berger. Combined Doppler Radar and Inertial Naviagation Systems, D. B. Duncan. The General Theory of Comb Filters, G. T. Flesher and G. I. Cohn. The Simplest Crystal Filter with Symmetrical Frequency Response, T. R. O'Meara. Switching V. H. F. Power with Semiconductor Diodes, R. M. Mattson and S. H. Liu. A Low Reflection Dielectric Waveguide Stepped Taper, R. A. Whiteman, H. Zucker, and C. M. Knop. Results of the IGY Satellite Program, W. H. Pickering. Preliminary Assessment of the IGY, A. H. Shapley. The Aurora, A. M. Peterson. A Transistorized Amplitude Distribution Analyzer Employing Digital Techniques, D. Hoffman and E. Schutzman. Application of Direct-Drive Servomotors to Gyro Platforms, S. G. Nelson. Effects of Variation in Carrier Frequency on the Performance of Carrier Control Systems Utilizing Two-Phase Servo Motors, E. W. Mehelich and G. J. Murphy. A New Method of Precision Control for Large Antenna Systems, A. Fein. Probability of Continuous Tracking in the Presence of Random Noise, F. E. Alzofon and S. E. Rauch. A System for the Accurate Determination of Ultrasonic Velocity in Solids, R. L. Forgacs. Resistivity Measuring Techniques in Semiconductors, H. G. Rudenberg. Synthesis Applications of Paramount and Dominant Matrices, P. Slepian and L. Weinberg. The Digital Computer as a Tool for Network Analysis, C. V. Anderson and M. B. Reed. Oversize Circular Electric Waveguide Components, A. C. Todd and R. E. Saxe. The Design of a Single-Layer Microwave Absorbing Material, D. L. Waidelich. Generalized Error Functions for Zero-Memory Nonlinear Systems with Random Inputs, H. R. Leland. Approximation of Autocorrelation Functions by a Series of Damped Cosine Functions, D. T. Friest and R. G. Brown. Design of a Delay Line for Analog Correlator, T. R. Benedict, H. S. Min, V. C. Rideout, and W. B. Swift. Overmodulation of a Carrier by Sine Wave and Gaussian Noise, D. R. Rothschild. A High-Speed Transistorized Digital-to-Analog Decoder, B. A. Antista. Optical Information Handling with Thin Magnetic Films, L. Kleinrock. A Drift Compensated Operational D-C Amplifier Employing a Low Level Silicon Transistor Chopper, W. Hochwald and F. H. Gerhard. The Radar Interference Problem, S. O. Newman and K. H. Chase. Detection of Radar Signals by Direct Measurement of Their Effect on Noise Statistics, G. I. Cohn and L. C. Peach. Use of Raydist System for Inertial

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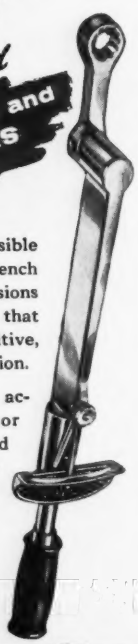

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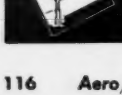

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Solid State Magnetic and Dielectric Devices. Edited by H. W. Katz. New York, John Wiley & Sons, Inc., 1959. 542 pp., diagrs., tables. $13.50.

The purpose of this book is to present an account of the solid-state devices and components developed from the ferrites and titanates, two significant new solid-state materials. The book begins with a classical treatment of magnetization and polarization, and later shows the general application of these principles to electrochemical phenomena, to square loop material, and to microwave frequencies. The remaining chapters of the book are concerned with certain magnetic and dielectric devices. It is expected that the book will be useful to readers interested in new computer components, new materials for filters, and delay lines. Information is also included on miniaturized filters, the theory of magnetic recording, and microwave applications.

The author is Manager, Dielectric and Magnetic Devices Subsection, General Electric Co.

HELICOPTERS

Helicopter Dynamics and Aerodynamics. P. R. Payne. New York, The Macmillan Co., 1959. 442 pp., illus., diagrs., tables. $17.

The present volume, which was written by a practicing designer of rotating wing aircraft, is keyed to the requirements of the industry and to helicopter engineers rather than to an academic study of helicopter theory. The actual mechanics of design will be considered in a companion volume together with the allied subjects of helicopter economics, and those aspects of power-plant design which affect the project design stage. An attempt has been made to introduce the subject of dynamic stability in such a way as to enable the reader to undertake his own analytical developments. Dynamic stability in hovering is examined in detail, but at the time of writing it was felt that it could not usefully be done for stability in forward flight because of the number of uncertainties involved. The available published works on the subject are referenced in *Appendix* 1. The application of existing theoretical treatments will be illustrated also in the companion volume.

Contents: (1) General Aerodynamics. (2) Induced Aerodynamics. (3) Fundamentals of Rotor Dynamics. (4) Dynamics of Rotors with Hinge Constraint. (5) Flapping Stability and Blade Movements in Gusts. (6) Performance. (7) Stability and Control (8) Rotor Vibration. (9) Ground Resonance and Vibration Due to Rotor Resonance. (10) Control Loads and Vibration. (11) Blade Flutter and Rotor Weaving. (12) Blade Flexing and Resonance. Appendix 1, References to Literature. Appendix 2, Trigonometric Identities. Index.

MATHEMATICS

Analysis of Linear Systems. David K. Cheng. Reading, Mass., Addison-Wesley Publishing Inc., 1959. 431 pp., diagrs., tables. $8.50.

This text on analysis of linear systems furnishes a complete exposition of the two essential steps involved in the analysis of a physical system: the setting up of the mathematical equations that describe the system in accordance with physical laws, and the solution of these equations subject to appropriate initial or boundary conditions. A primary purpose of the author, who is Professor of Electrical Engineering, Syracuse University, is to introduce the Laplace transform method of solving linear differential and integrodifferential equations. Fourier series and Fourier integral are first reviewed, and a discussion of Fourier transforms leads logically and directly to Laplace transforms. The book may be used by either advanced undergraduates or beginning graduate students.

Analysis of Straight-Line Data. Forman S. Acton. New York, John Wiley & Sons, Inc., 1959. 267 pp., diagrs., tables. 267 pp., diagrs., tables. $9.00.

This book presents a detailed treatment of one important aspect of engineering statistics, the analysis of experimental data that can be described in terms of linear relationship. Emphasis is placed on matching the method of analysis to the type of information to be extracted and the influence of the assumed statistical model on the success of the analysis. To make the treatment practical, short-cut computational techniques are stressed, and nonparametric and low-arithmetic techniques are combined in a unified exposition. Theory has been included when deemed helpful, and the philosophy underlying a method is frequently stressed.

The author is Associate Professor of Electrical Engineering, Princeton University.

MISSILES, ROCKETS

Basics of Missile Guidance and Space Techniques. Marvin Hobbs. New York, John F. Rider Publisher, Inc., 1959. Vol. 1, 144 pp., illus., diagrs., $3.90. Vol. 2, 146 pp., illus., diagrs. $3.90.

These volumes are intended for use as aids in the training of technical and semitechnical personnel, and for the general reader.

Contents: *Vol. 1.* The Evolution of Guidance Techniques. Fundamentals of Control and Guidance. Radio and Radar Command Links. Guide Beam, Doppler, and Homing Techniques. Gyroscopic Fundamentals. Inertial and Celestial Navigation. Computer Applications. Actuators and Related Components. Glossary. Index.

Vol. 2. Testing and Telemetering. Space Exploration by Optics and Electronics. Satellite Theory and Practice. Satellite Monitoring and Tracking. Applications of Earth Satellites. Navigation and Telemetry in Space. Electronic Components for Space Applications. Glossary. Index.

Rocket Encyclopedia Illustrated. Edited by John W. Herrick and Eric Burgess. Los Angeles, Aero Publishers, Inc., 1959. 607 pp., illus., diagrs. $12.50.

In addition to extensive coverage of current terms, the editors have also included many that are no longer used but which may be encountered in older literature, as well as vernacular terms which are common at proving grounds and test sites. There are several long articles about the operation of rockets and the rocket industry, together with biographies of a few pioneers and scientists.

Nearly all entries are presented in two parts: (1) a concise, highly technical definition, and (2) an explanation which gives more detailed information about the term in language intended to be within the capabilities of a high-school graduate.

Mr. Herrick is associated with Space Technology Laboratories; Mr. Burgess is with the Data Instruments Division, Telecomputing Corp.

NUCLEAR ENERGY

Project Sherwood—The U.S. Program in Controlled Fusion. Amasa S. Bishop. Prepared for the U.S. Atomic Energy Commission. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1959. 216 pp., illus., diagrs., tables. $5.75.

The book presents a brief account of the development of the United States program in controlled thermonuclear reactions (Project Sherwood) from its inception in 1951 to the early part of 1958. Written mainly for those with little familiarity with the subject, the purpose is to give the reader some knowledge of the program, the basic problems involved, the approaches being pursued in the United States, the difficulties encountered, the present status of the effort, and the outlook for eventual success. Specific chapters are devoted to the basic principles of controlled fusion; the problem of confinement; "pinch," "stellarator," "magnetic mirror," and "molecular ion ignition" programs; plasma diagnostics; the question of stability; the cusped geometry program; shock-wave experiments; the Astron program; and the development of other projects.

The author was formerly Chief, Controlled Thermonuclear Branch, Division of Research, USAEC, and is now the Commission's European scientific representative.

PHYSICS

Extensive Air Showers. William Galbraith. New York, Academic Press, Inc., 1958. 211 pp., diagrs., tables. $7.50.

This book is primarily concerned with those incoming particles of greatest energy in the cosmic radiation, the arrival of which is indicated by the generation within the 20 km. of atmosphere above the earth of a complex sequence of events known as extensive air showers. Intended for physics students and graduates, the author, who is at the British AERE, Harwell, details the work in the field which has been carried out over the last 20 years, since the discovery of the phenomenon. Generally, the literature references do not extend beyond the end of 1957.

RESEARCH

Scientific Research and Development in Colleges and Universities: Expenditures and Manpower, 1953–54. National Science Foundation. Washington, Superintendent of Documents, 1959. 173 pp., tables. $1.00.

The conduct of research at educational institutions is characterized by a number of issues, some of which involve sources of financial support and man power for furthering scientific progress. Although this report is confined to funds for scientific research and development and to scientific man power, it may shed light not only on some specific problems but also on the broader aspects of the Government's needs in this area and the nation's educational strength. The four sections of the report deal with an outline of an approach to the survey, the costs of R&D in

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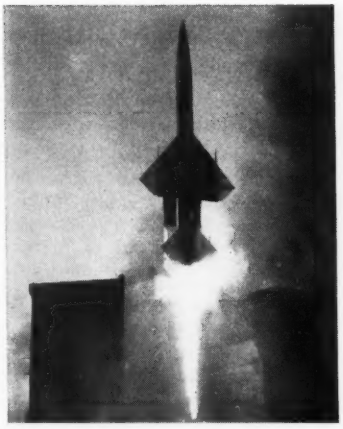

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THE ORGANIZATION

Cornell Aeronautical Laboratory is a not-for-profit corporation wholly owned by Cornell University. It is financially self-supporting and operated for the sole purpose of advancing and enlarging scientific and engineering knowledge. Current research volume is about 14 million dollars per year with slightly more than 1000 employees.

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colleges and universities, professional scientific personnel in colleges and universities, and the relationships of expenditures and personnel data. Appendixes are devoted to statistical tables, a tabulated summary of scientific professional personnel in special research organizations, and samples of the forms used in the survey.

SPACE TRAVEL

Proceedings of Lunar and Planetary Exploration Colloquium. Held January 12, 1959, at Griffith Observatory, Los Angeles. Downey, Calif., Missile Division, North American Aviation Inc., 1959. 53 pp., illus., diagrs., tables.

Contents: Geochemical Implications of Lunar Degassing, J. Green. The Alphonsus Story, D. Alter. High-Velocity Impact Studies, C. N. Scully. Sonic Velocity in Possible Lunar Surface Materials, J. Green. The Problem of the Martian Blue Haze, A. G. Wilson. Comparison of Lunar and Martian Features, C. Tombaugh. Results of Pioneer I Flight, C. P. Sonett. Results of Pioneer III Flight, A. R. Hibbs and C. W. Snyder.

STRUCTURES

Theoretical Elasticity. Carl E. Pearson, Cambridge, Mass., Harvard University Press. 1959. 218 pp. $6.00.

This book grew out of a series of lectures given to graduate students in applied mechanics at Harvard University. It discusses modern methods of elasticity theory in a form which does not require extensive mathematical experience, and provides a compact and convenient summary of such methods. With the emphasis on general results rather than on detailed examples, the subject areas covered are vectors, rotation of a coordinate system, Cartesian tensors, stress, deformation, basic equations of linear elasticity, general solutions, variational methods, thermoelasticity, time-dependent problems, and nonlinear elasticity.

The author is with the Engineering Division, Arthur D. Little, Inc.

THERMODYNAMICS

Thermodynamics. Gordon J. Van Wylen, New York, John Wiley & Sons, Inc., 1959. 567 pp., diagrs., tables. $7.95.

With the stress on engineering perspective, this text deals with the physical and mathematical aspects of thermodynamics. The first section discusses basic definitions and concepts; the concepts of availability and irreversibility; the ideal gas; the mixture of ideal gases and vapors; an analysis of the first law of thermodynamics, including flow into an open system and the conservation of mass; and the second law, which includes the consideration of Kelvin-Planck and Clausius statements, the Carnot cycle, the thermodynamic scale of temperature, the inequality of Clausius, and the principle of the increase of entropy.

The second section treats processes in reciprocating machinery; power and refrigeration cycles; one-dimensional flow through nozzles and orifices; axial flow through blade passages; the mathematical and physical aspects of Maxwell relations and equations of state; chemical reactions with emphasis on combustion; and equilibrium, with particular attention to chemical equilibrium of ideal-gas mixtures.

Mr. Van Wylen is Chairman, Department of Mechanical Engineering, University of Michigan.

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For information on IAS Library Services see page 67.

Change of Address

Since the Post Office Department does not as a rule forward magazines to forwarding addresses, it is important that the Institute be notified of changes in address 30 days in advance of publishing date to ensure receipt of every issue of the *Journal* and *Aero/Space Engineering*.

Notices should be sent directly to the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

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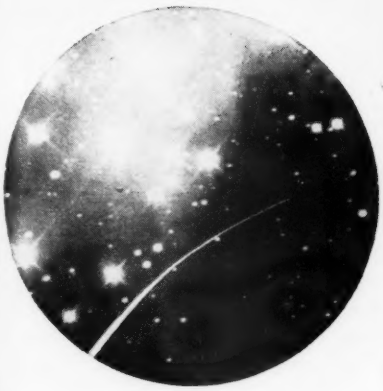

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Lockheed's capabilities in gas dynamics and thermodynamics are unsurpassed in private industry. Basic work is being performed in boundary layer flow and heat transfer; cooling and insulation; thermodynamic flight test; instrumentation; rocket motor controls and nozzle structures; reentry and materials; thin film thermometry; and measurements of dissociation and re-combination reactions.

Fundamental studies include hypersonic aerodynamics; environmental effects on satellite surfaces, magnetohydrodynamics; ultra-violet and infrared radiation from high temperature air flows; structure of hypersonic shock waves; new measurement methods; analysis of boundary layers near melting surfaces and study of lag or non-equilibrium in high speed flow through shock waves.

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Hughes has several hundred openings for engineeers and physicists whose training and experience are applicable to the research, development, design and testing of airborne electronic equipment for use in supersonic military aircraft; in solid state physics, nuclear electronics, industrial dynamics, and related areas.

Use of the following form will, we hope, reduce to a minimum the inconvenience of submitting an employment inquiry, yet will still permit us to give you a reasonably definitive reply.

Please airmail to:
Mr. Robert A. Martin, Supervisor, Scientific Employment
Hughes Research and Development Laboratories
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- ☐ OTHER: _____
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I have had professional experience in the following specific areas:

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- ☐ DIGITAL COMPUTERS
- ☐ GUIDANCE DEVICES
- ☐ MICROWAVES
- ☐ STRESS ANALYSIS
- ☐ INDUSTRIAL DYNAMICS
- ☐ MATERIALS
- ☐ SYSTEMS ANALYSIS
- ☐ R-F CIRCUITS
- ☐ RELIABILITY
- ☐ ATOMIC AND/OR SOLID STATE PHYSICS
- ☐ INSTRUMENTATION
- ☐ ELECTRO-MECHANICAL DESIGN
- ☐ OTHER: _____
- ☐ _____
- ☐ _____

I have had a total of _____ years of experience.

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Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and eligible organizations offering employment to specialists in the aero/space industry. Any member or eligible organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Electronic Engineers and Physicists—for Staff, design, and development engineering in connection with research, design, and development in the fields of data handling, servodevices, instrumentation, optics, measurement, plotting, feedback control, computing, and infrared. Servo Corp. of America, New Hyde Park, Long Island, N.Y., concerned with the research, engineering, and production of electronic systems and devices for both military and commercial users. Send detailed résumé to Felix Gardner.

Marketing Manager—Aircraft Instruments: Progressive aircraft electronic equipment manufacturer has an immediate opening for top-notch executive sales manager to assume full responsibility for its marketing operations in New York City. Must be dynamic salesman and administrator who, given full support of the organization, can build on his company's established position, open new markets, develop new products, have intimate knowledge of the overall military field with established buying contacts in it, operate as a member of top management staff. Please forward work history, education, earnings, etc., to Manager, Industrial Relations, Avien, Inc., 58-15—Northern Blvd., Woodside 77, N.Y.

Faculty Openings—Department head and one staff member in Aeronautical Engineering and two staff members in Applied Mathematics—Mechanics, all with doctorates, for undergraduate, graduate, and research programs. Apply to Dean, College of Engineering, University of Cincinnati, Cincinnati 21, Ohio.

Aerodynamicists—The Computation and Analysis Laboratory of the Naval Proving Ground has openings in applied research for aerodynamicists having strong backgrounds in both theoretical and experimental missile aerodynamics, preferably throughout the subsonic to hypersonic speed ranges. A working knowledge of advanced mathematics is highly desirable. Appointees will work in an established and growing laboratory which is involved in determining the dynamic performance of missiles and space vehicles utilizing one of the world's fastest and most accurate digital computers, the Naval Ordance Research Calculator (NORC). Positions with starting salaries up to $11,595, depending upon the qualifications of applicants, are available. Inquiries should be addressed to Industrial Relations Director, Naval Proving Ground, Dahlgren, Va.

Operations Research Analysts—The USAF and other Department of Defense agencies need Operations Research Analysts for positions in Washington, D.C., and throughout the U.S. A few positions may also be filled at overseas locations. The salaries range from $7,510 to $12,770 a year. To qualify, applicants must have had at least 7 years of appropriate experience or a Ph.D. degree in one of the specialized fields to which appointments are to be made, or a combination of such experience and education. Full information regarding the requirements for these positions is contained in civil service examination Announcement No. 193B. This announcement and application forms may be obtained at many post offices throughout the country, or from the U.S. Civil Service Commission, Washington, D.C. Applications will be accepted by the Board of U.S. Civil Service Examiners, Headquarters USAF, Washington 25, D.C. until further notice.

Professor—Major permanent faculty positions available in fields of aerodynamics, structures, thermodynamics, and engineering mechanics. Desire men who either are, or who will be, outstanding teachers in both graduate and undergraduate courses. Ph.D. degree or equivalent required, plus active interest in research and curriculum development. Salary range $10,000 plus, depending on qualifications. Please send complete details to Dean of Engineering, University of Detroit, Detroit 21, Mich.

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engineers • scientists

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- Orbital Mechanics
- Interplanetary Flight
- Re-Entry Flight

AERODYNAMICS
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- Hypersonic Flow
- Physics of Rarefied Gases
- Strong Shock Phenomena

There's a growing atmosphere of technological excitement these days at Republic Aviation Corporation. Accelerating space study contracts plus a number of original proposals in such areas as ICBM's, air-to-surface ballistic missiles and unique aircraft are responsible for this environment that adds incentive for you to use your best thinking. The scope of challenge at Republic ranges from design concept to proof of feasibility. Working within a flexible framework of theoretical and experimental research, you will be able to define your own approach in attaining the requirements of your assignment.

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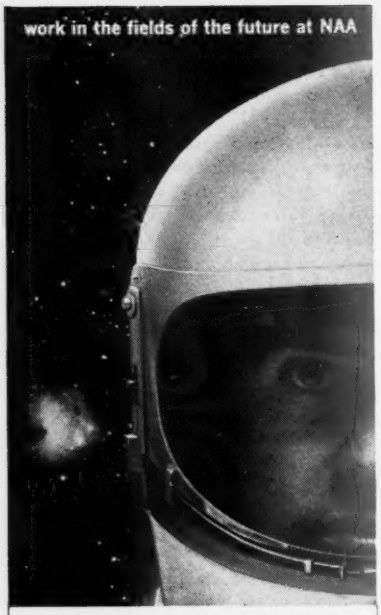

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Exceptional opportunities in the field of thermodynamics.

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Heat Transfer

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THE LOS ANGELES DIVISION OF

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ENGINEERS AND SCIENTISTS

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The Space Technology Operation offers the highly desirable combination of new facilities and advanced equipment, located in California's finest environment for living and raising a family. Investigate these exceptionally rewarding positions now:

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Aerodynamic design and testing
Rocket engine development
Rocket nozzle and re-entry materials
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Combustion and detonation theory
Combustion thermodynamics
High temperature structural plastics & ceramics
Advanced structures
Rocket vehicle systems

MISSILE DEFENSE

Supersonic aerodynamics
Aerothermodynamics
High temperature heat transfer
Space physics
Re-entry programs

ASTRO SCIENCES

Space electronics
Guidance & control
Communications
Instrumentation
Experimental physics
Plasma and magneto-hydrodynamics studies

Visit Aeronutronic's exhibit booth 3822-24 at the WESCON show.

Qualified applicants are invited to send resumes and inquiries to Mr. R. W. Speich, Aeronutronic, Dept. 13, Box 451, Newport Beach, California.

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Mr. Stanley M. Little
Boeing Airplane Company
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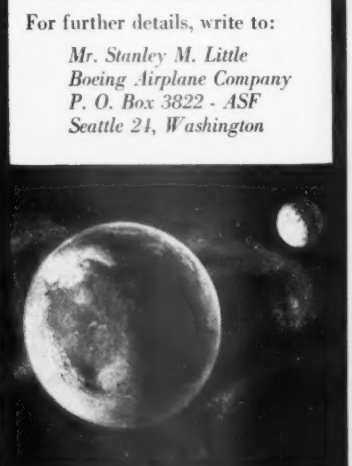
Seattle 24, Washington



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years' experience in application of systems analysis techniques to automatic flight control systems. Knowledge of advanced mechanics essential. Requires U.S. citizenship, B.S., M.S., or Ph.D. in E.E., Math, Physics, or Aeronautics. Send résumé to D. Johnston, Systems Technology, Inc., 1630 Centinela Ave., Inglewood 3, Calif.

Available

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917. Design Engineer—B.S. in Ae.E.: Age 36; 8 years' experience with airframes, escape capsules, wind-tunnel models, sled tests, and rocket engines. Familiar with space flight problems; private pilot; ex-paratrooper. Seeking employment in design, project, or test department of large or small company. Will relocate. Also capable of supervisory and administrative duties.

916. Engineer—Senior grade engineer desires administrative, supervisory, or possibly technical sales opportunity. Age 29; B.S.M.E., 1952. Will receive an M.B.A. within one year. Seven years of aircraft experience in preliminary structural design, including stress and aeroelasticity utilizing a direct analogy computer technique, structural and environmental testing, and production supervision (as foreman).

914. Engineering Executive—Chief Engineer, Manager of Engineering. Graduate electronic engineer, advanced studies in electronics and management. Current position, manager of engineering, manager of research and advanced developments with medium-sized firm making aircraft and missile instruments. Many years' experience and proved record of accomplishment in engineering, research, management, and administration in the fields of military and missile electronics, atomic energy applications and weapon systems, servomechanisms, instrumentation and controls. Seeking active, expanding situation where my background and capabilities can be most effectively translated into profit and growth.

913. Engineer—B.S.M.E., University of Michigan. Graduate work in nuclear engineering and business administration. Ten years' experience primarily in gas turbines and nuclear propulsion systems. Prefer California. Résumé upon request.

912. Project Engineer—B.S.Ae.E., 1948; Age 34. Project engineer, advanced weapons systems. Extensive background and familiarity with many existing advanced weapons. Familiar and well experienced in management and direction of all phases of proposal designs and R&D designs, to production, on advanced guidance systems, electronic packaging, and complete weapons systems. Available soon for a management position of increased challenge and equal opportunity. Preferred locations are Southern California, San Fernando Valley (California), or Florida. Please note position description in your reply.

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- VTOL and STOL aircraft
- Advanced combat and transport aircraft
- Air launched and ground launched missile systems
- Manned and un-manned satellites
- Interplanetary launching and recovery systems

Applicants should have 5 years' experience in the analysis of airframe and missile components. An ability to apply classical methods in determination of internal load distributions and stresses in complex structures is necessary. Familiarity with the effects of high temperature environment on structural material, design and analysis will be helpful.

You will work in Republic's new $14,000,000 Research Center scheduled for completion this year.

Send your resume in confidence to:
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Engineering Employment Mgr., Dept. 2H

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Published Annually by

INSTITUTE OF THE AERONAUTICAL SCIENCES
2 East 64th Street • New York 21, N.Y.